CONNECTICUT DEPARTMENT OF TRANSPORTATION
Reconstruction of I-84
Washington Avenue to Pierpont Road
Waterbury, CT
ConnDOT Project No. 151-273
Federal Aid Project No. NHI-84-2 (172) 33

FINAL SCOUR REPORT
BRIDGE NO. 06284
I-84 EASTBOUND EXIT 25 OFF-RAMP TO HARPERS FERRY ROAD OVER THE MAD RIVER

Waterbury, Connecticut
New Haven County

Prepared By:

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July 2006
Revised May 2014

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Executive Summary

This scour report has been prepared for the final design of proposed Bridge No. 06284, the I-84 Eastbound Exit 25 Off-Ramp to Harpers Ferry Road over the Mad River. This bridge is one of six (6) waterway crossings over the river to be constructed under the State Project No. 151-273, improvements to Interstate 84 in Waterbury from Washington Avenue east to Pierpont Road. The subject 4.3-kilometer (2.7 mile) long highway project has been designed by Ammann & Whitney (formerly Berger, Lehman Associates, P.C. – BLA).

The location of the new bridge is approximately 190 meters (625 ft) downstream of the existing crossing for the Eastbound Exit 25 Off-Ramp (existing Structure No. 06284). This relocation is needed to accommodate shifting the I-84 alignment 60 meters (200 ft) southerly in this area to improve the horizontal geometry of the highway. The new crossing is located within the limits of a proposed relocation of the Mad River (see *River Relocation Report, Mad River, Beaver Pond Brook).*

The bridge will be a single span structure on a curved alignment with the superstructure elevated at least 6.5 meters (21.3 ft) above the 100-year flood, and 5.8 meters (18.9 ft) above the 500-year flood elevations. The proposed substructure will consist of concrete abutments founded on end bearing H-piles terminating in glaciofluvial deposits. The proposed structure will be placed skewed to the watercourse (43º). The bridge is located near the downstream limit of the proposed Mad River relocation, and only 40 meters (130 ft) downstream of proposed I-84 Bridge No. 05774. However, the resulting backwater from the subject Off-Ramp Bridge No. 06284 will not extend to the upstream I-84 bridge.

This report finds that the proposed bridge will mainly be affected by the local scour at the westerly abutment. The scour potential will be greatest during the 500-year event. The computations indicated the depth of scour at the abutment could be as much as 1.41 m (including the long-term scour), which still does not expose the piles supporting the substructure.

Table 1. NBIS Ratings and Scour Related Design Information

Recommended NBIS Item 113 Rating	8 (for 100-year design discharge)
Recommended NBIS Item 71 Rating	9
Recommended NBIS Item 61 Rating	8
Scour Risk Designation	Low Risk
Depth of Potential Scour (500-year)	1.41 m (Abutment #1 – West); 0.9 m (Abutment #2 – East)
Foundation Type	Abutment Footings on Piles
Recommendations	Foundation Designed for Predicted Scour (Long-term + Contraction)

Reference Reports

The following reports, prepared under separate covers for the project, should be referenced for more detailed information pertinent to the hydrology and hydraulics for the subject reach of the Mad River and the hydraulic design of Bridge No. 06284.

- *Overview Report for Hydraulic Design, CT DEP Flood Management Certification & FEMA Conditional Letter Of Map Revision (CLOMR), Mad River & Beaver Pond Brook, Waterbury, Connecticut* prepared by ConnDOT, July 2006.
- *Hydrologic Report, Mad River* prepared by BLA, September 1999
- *Hydraulic Analysis for Design Report, Mad River* prepared by ConnDOT, revised April 2014.
- *Final River Relocation Report Mad River & Beaver Pond Brook* prepared by BLA, January 2004 and revised by ConnDOT, April 2006.
- *Mad River Floodplain/Floodway Analysis Report for FEMA CLOMR & CTDEP Flood Management Certification* prepared by ConnDOT, revised April 2014.

Project Overview

The information presented in this report are mostly derived from the hydraulic analyses performed using the DOT "Design" discharges as presented in the *Hydraulic Analysis for Design Report, Mad River* prepared by ConnDOT, revised April 2014. For complete hydrologic information refer to *Hydrologic Report, Mad River* prepared by BLA (Ammann & Whitney), September 1999. The summarized hydrologic information is shown in the table below.

Table 2. Hydrologic Information

Watershed Area:	62.26 km^2 (24.04 mi^2)- Large Structure
Discharges:	100-Yr: 176.98 cms (6,250 cfs)
	500-Yr: 269.01 cms (9,500 cfs)
	Overtopping: >500 year

See the Overview Report referenced above for an overview of the project, the existing and the proposed project conditions.

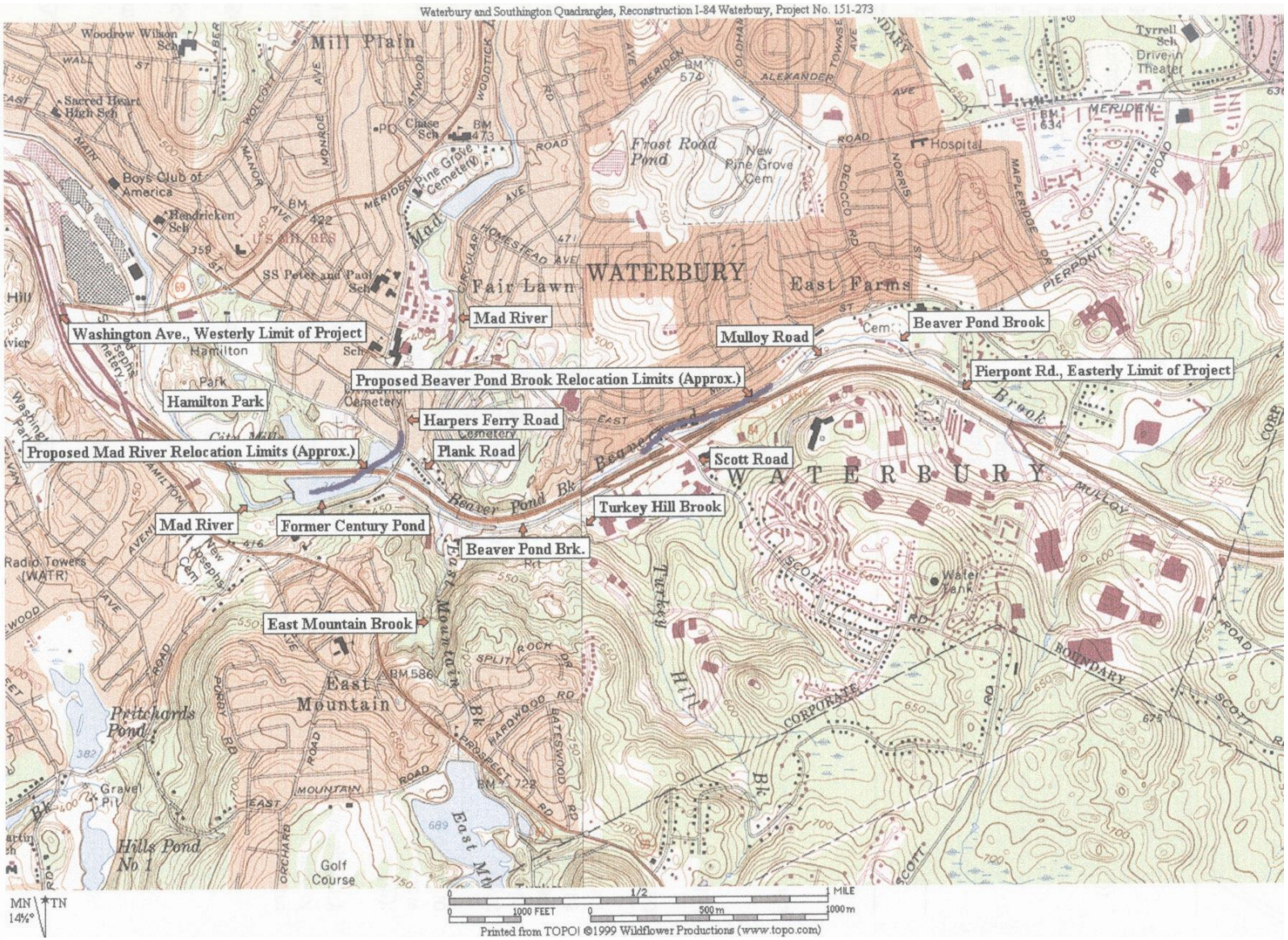


FIGURE 1 - PROJECT LOCATION PLAN

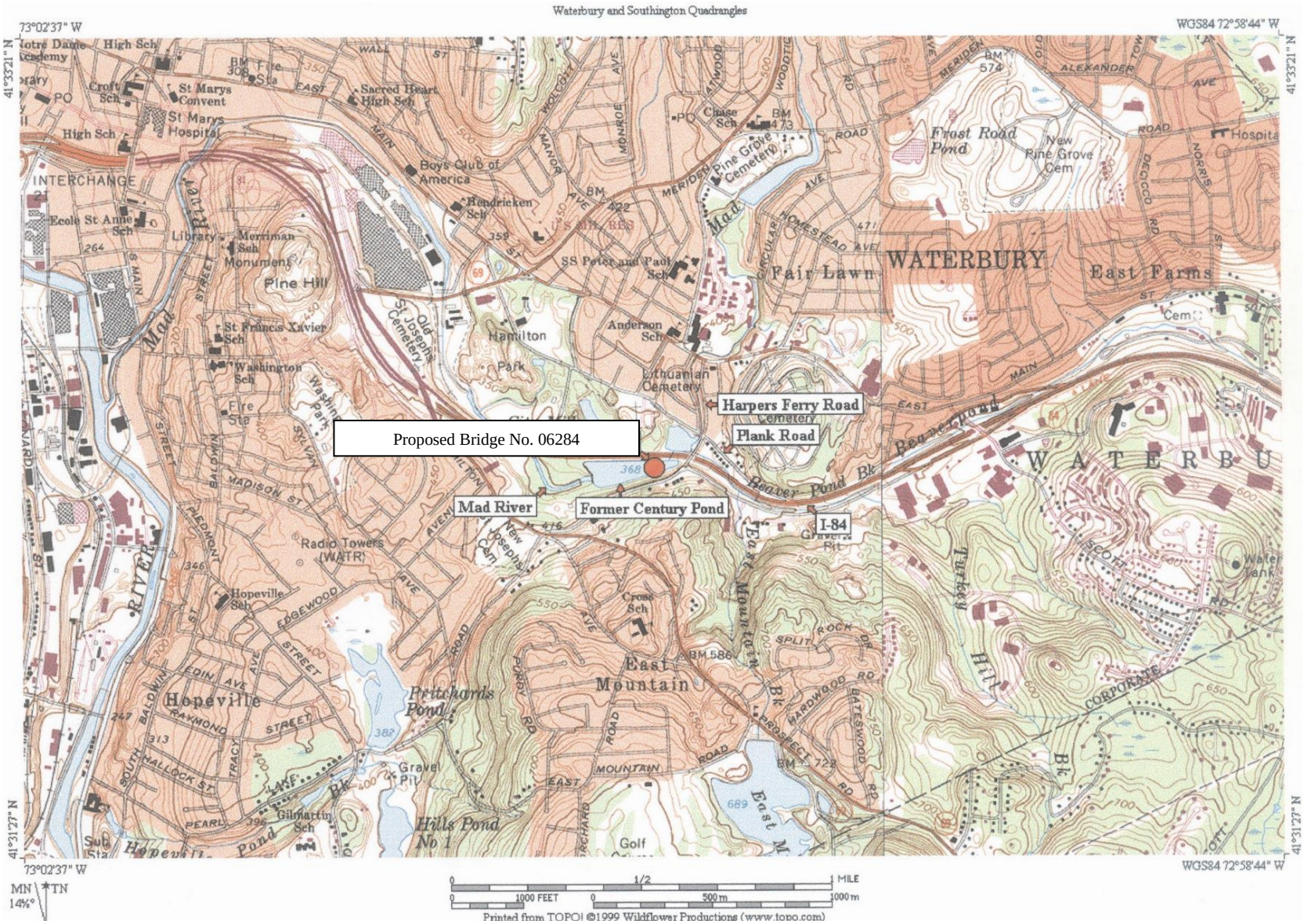
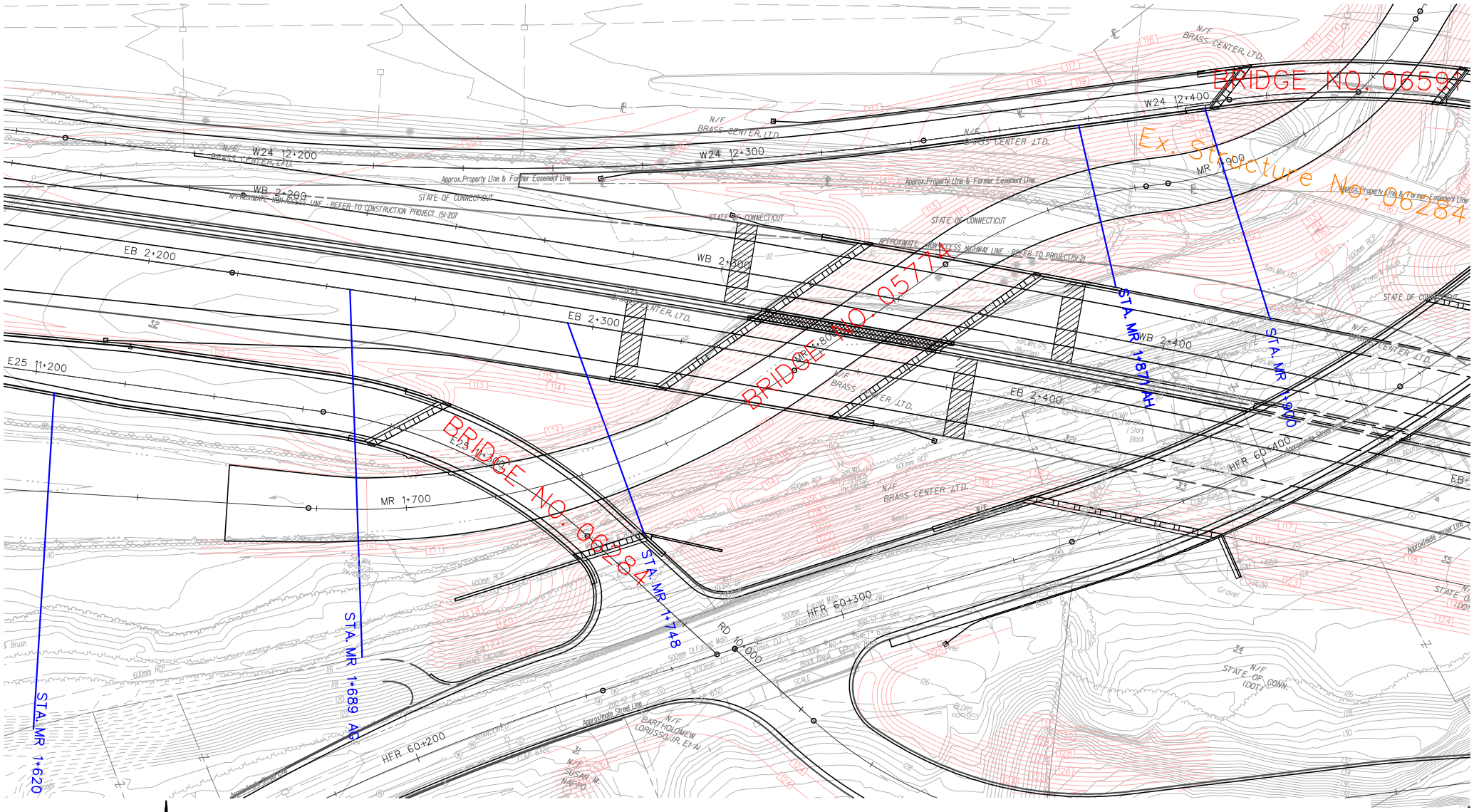


FIGURE 2 - STRUCTURE LOCATION PLAN



PROPOSED BRIDGE NO. 06284 OVER MAD RIVER

CROSS SECTION LOCATION PLAN

I-84 Waterbury, Project No. 151-273 (In State Plane Coordinate System)

CONNECTICUT COORDINATE GRID

NAD 1983

SCALE IN METERS

0 10 20 40

FIGURE 3 - CROSS SECTION LOCATION PLAN (VICINITY OF BRIDGE)

Report Background

This scour report with the accompanying final hydraulic report has been prepared as part of the final design for Bridge No. 06284, the Exit 25 On-Ramp to Westbound I-84 over the Mad River. The location of the new bridge is approximately 190 meters (625 ft) downstream of the existing crossing. This relocation is needed to accommodate a southerly 60-meter (200-ft) realignment of I-84 in this area. The new crossing is also located within and near the downstream limit of a proposed relocation of the Mad River.

Scour depths have been estimated following procedures set forth by the Federal Highway Administration in Hydraulic Engineering Circular No. 18 (HEC-18), *Estimating Scour at Bridges*, May 2001. As recommended on page 9.B-2 of the *2000 ConnDOT Drainage Manual*, the following Amended Local Abutment Scour Equation was utilized:

$$Y_s/Y_a = [2.27\ K_1\ K_2\ (L'/Y_a)^{0.43}\ Fr^{0.61}] + 0.05 \qquad \text{(ConnDOT)}$$

This equation predicts scour depths for the 50th percentile as compared to the more conservative HEC-18 version of Froehlich's equation (equation 7.1, page 7.8), which would have encompassed 98% of the laboratory produced scour holes from the original study. The HEC-18 version of Froehlich's equation is as follows:

$$Y_s/Y_a = [2.27\ K_1\ K_2\ (L'/Y_a)^{0.43}\ Fr^{0.61}] + 1 \qquad \text{(HEC-18)}$$

A comparison of the two local abutment equations shows that ConnDOT's version will predict scour depths $0.95Y_a$ less than proposed by HEC-18. Y_a is the average depth of floodplain flow at the upstream approach cross section.

The discharges used in this investigation have been approved by ConnDOT and are presented in the September 1999 *Hydrologic Report, Mad River, Waterbury, Connecticut* prepared by BLA (Ammann & Whitney). The discharges reported in the original 1979 and currently effective 2013 Waterbury Flood Insurance Studies are 25-30% lower than those approved by ConnDOT.

The hydraulic analysis completed for this investigation utilized HEC-RAS version 4.1.0 assuming mixed flow conditions. A CD containing the HEC-RAS data files is included in the referenced *Hydraulic Analysis for Design Report, Mad River*.

To avoid confusion between existing and proposed crossings in the report, the existing crossing is referred to as "Structure" followed by the ConnDOT bridge number, whereas the proposed crossing is called out as "Bridge" (e.g. existing Structure No. 06284 versus proposed Bridge No. 06284).

Proposed Bridge

This new Off-Ramp crossing will be located approximately 40 meters (130 ft) downstream of the proposed I-84 crossing (Bridge No. 05774) over the Mad River, or roughly 190 meters (625 feet) downstream of the existing Structure No. 06284, as indicated previously. This location is also encompassed within a 520-meter (1,706-ft) reach of the Mad River which is to be relocated.

Proposed Bridge No. 06284 will be a single span bridge with a clear span of approximately 51.5 meters (169 ft), measured along the roadway baseline between the abutment faces. Its superstructure will consist of welded steel plate girders. The width of the structure, perpendicular to the roadway baseline, will be 14.3 meters (47 ft). The roadway will be on a curved alignment at approximately a 43° skew to the river baseline. The substructure will consist of concrete abutments founded on end bearing H-piles terminating in glaciofluvial deposits. In the Proposed Condition hydraulic model, the subject bridge is located at River Station 1727.5.

According to the hydraulic analysis (based on DOT Design Discharges), superstructure of the proposed bridge will be elevated well above the river with a minimum underclearance of approximately 6.5 m (21.3 ft) to the 100-year, and 5.8 m (18.9 ft) to the 500-year water surface elevations. The flow velocity through the bridge opening will be 2.98 m/s (9.78 ft/s) and 3.44 m/s (11.29 ft/s) respectively for the 100- and 500-year discharges.

Using the results of the analysis, the bridge abutments are located to minimize obstruction of flood flows. The elevation of the 100-year design flood is approximately at the base of the westerly abutment, Abutment 1. The base of Abutment No. 2, the easterly abutment, is elevated above the 500-year flood level. Furthermore, as the flood flows upstream and through the bridge will mostly be contained within the trapezoidal main channel, the resulting energy losses and subsequent backwater from contraction is minimal. Accordingly, the backwater from this bridge will not affect the proposed I-84 Bridge No. 05774, even though they are located in relatively close proximity.

Comparing the proposed 100-year waters surface profile to the existing condition profile reveals that the new bridge will cause increases of 0.23 m (0.75 ft) and 0.35 m (1.15 ft) at the upstream and downstream faces respectively. These increases will occur for a short distance along the river, mainly inside the bridge, and are well contained within the ConnDOT right-of-way. These increases can be attributed to the geometric changes in the river.

Upstream of the subject off-ramp bridge through the proposed I-84 crossing, however, the resulting waters surface profile of the proposed condition will be lower than the existing condition. The profile will also be lower downstream of the bridge to the breached Century Dam, or to approximately 150 meters (490 ft) downstream.

The proposed bridge site falls within the reach of the Mad River affected by the 1998 partial breach of Century Dam, which is located approximately 390 meters (1,280 ft) downstream of the existing Structure No. 05774. Prior to the breach, City Mills Pond extended upstream through the existing I-84 crossing (Structure No. 05774), terminating approximately at the downstream side of the next upstream roadway crossing (Plank Road Structure No. 05668). At the time of the breach, the channel immediately upstream of the dam was apparently provided with riprapped channel banks for a length of approximately 130 meters (425 ft). Upstream of this segment to roughly the midpoint between the existing Structures No. 06284 and No. 05774, the existing channel showed signs of erosion along the riverbanks displaying lateral instability of the river caused by the breach of the dam. The riverbanks are actively eroding, forming several shallow meanders. The erosion is beginning to encroach into a reported bulky landfill site which was apparently active during the dam breach project. The source of the landfill material is purportedly from the development of the Brass Mill Mall site in Waterbury.

In order to prevent the erosion in the post-project condition, the main channel bank having side slopes of 2H to 1V will be constructed using Standard Riprap with a bottom width transitioning from 14 meters (46 ft) to 12 meters (40 ft) in the vicinity of Bridge No. 06284. Just downstream of the subject bridge, the channel will match into the existing channelized stream section where it is more stable due the previously placed rirprap bank protection.

The overall vertical profile of the relocated channel will be maintained by a series of strategically placed riprap grade control structures. The general concept of the grade control structures is from the 1986 Swiss publication *Blockschwellen* (Block Ramps) by Whitttaker and Jäggi. These structures will serve as hard-points along the channel bottom to limit channel headcutting. Between the grade control structures, 600 mm (24 in.) of Gravel Streambed Material will be placed along the channel invert to simulate a "natural" riverbed. This substrate will maintain the continuity of sediment supply through the reach, similar to a natural channel. The gravel material will also serve as a foundation for the development of a diverse and productive aquatic habitat.

Scour Potential Assessment and Results

Scour computations were completed for the 100- and 500-year frequency discharges. The computations for the lower frequency discharges were not performed as the degree of contraction, velocity and other flow variables were found relatively moderate compared to the conditions under the above high frequency discharges.

The estimate of D_{50} was based on a soil sample of existing material taken in the vicinity of the proposed bridge (see Figure 4). The bottom of the proposed channel will actually be laid with Gravel Streambed Material which is intended as sediment supply medium, as indicated previously. However, the composition, thickness and the relative vertical location of this layer will change over time, as it is displaced and replenished with the sediment supply from upstream - mainly until the proposed channel stabilizes, and a balance in sediment transport is established. Moreover, as the median particle size of the proposed channel-bed material is larger than that of the soil sample, the d_{50} used in the computation is deemed to produce more conservative results.

Figure 4. Soil Sample (For estimating D_{50} for scour analysis)

Scour analysis Soil Sample #2 in vicinity of Station MR 1+720, northerly riverbank looking downstream, 12/7/00

Computed scour depths for the 100-and 500-year return frequencies are as follows:

Table 3. Summary of Computed Scour Depths

100 Year	Scour Depths (m)			
	Long-Term	Contraction	Amended Abutment	Amended Total
Abutment 1 (Western)	0.9	0.0	0.32	1.22
Abutment 2 (Eastern)	0.9	0.0	0.0	0.9

500 Year	Scour Depths (m)			
	Long-Term	Contraction	Amended Abutment	Amended Total
Abutment 1 (Western)	0.9	0.0	0.51	1.41
Abutment 2 (Eastern)	0.9	0.0	0.0	0.9

Long-term channel scour was assumed to be 0.9 meter (3 feet) to account for potential future channel degradation and will largely be controlled by the proposed riprap grade control structures. As discussed previously, the general concept of the grade control structures is from the publication *Blockschwellen* by Whittaker and Jäggi. The design assumes that the structures will act as hard-points along the channel bottom to limit channel headcutting. As scour holes develop downstream of the grade control structures, rocks from the grade control structures will launch into the scour holes. Eventually, equilibrium will be reached when a sufficient quantity of stone has been launched into the scour holes, completely armoring the holes, and preventing further channel degradation. The volume of the constructed grade control structure must be sufficient to provide enough rock to launch into the scour hole to an adequate depth to armor the scour hole and still provide grade control protection in its constructed location. The thickness of the proposed grade control structures (1+775 and 1+695) is 2 meters (6.6 ft) with a length, along the river baseline, of 6 meters (20 ft). It is assumed that the anticipated launching of the rocks could reduce the thickness of the grade control structure by as much as 0.9 meter (3 ft) and result in a corresponding lowering of the constructed channel profile (long-term channel degradation).

The computed scour depths are relatively minimal for discharges up to and including the 500-year event. This can mainly be attributed to the river channelization which reduces the contraction of flow through the structure. There is no abutment scour for the eastern abutment, as it is located outside the flood limits. In case of the western abutment, its downstream end sits closer to the main channel and obstructs the flow. Accordingly, the local scour is anticipated.

Structural Design Review and Conclusions

Footing

Page 2.4 of HEC-18 states:

> Placing the top of the footing or pile cap below the streambed a depth equal to the estimated long-term degradation and contraction scour depth will minimize obstruction to flood flows and resulting local scour.

For Abutment No. 1, the top of the footing has been located below the sum of the long-term and contraction scour depths for the 100-year design discharge. The base of Abutment No. 2 is elevated well above the elevation of not only the 100-year, but also the 500-year flood as well; therefore, the footing elevation was set without consideration of scour. Along this reach of the proposed channel, heavy riprap will be placed along both riverbanks, extending 3 meters (10 ft) vertically above and toed-in 2 meters (6.6 ft) below the river profile. This protection, although not considered a scour countermeasure, will reduce scour potential. This channel bank riprap protection has primarily been designed using the procedures described in the HEC-11. The detailed analysis is included in the referenced *Final River Relocation Report, Mad River & Beaver Pond Brook.*

Piles

The typical guideline for pile supported abutments is to design the substructure using normal factors of safety assuming the piles are unsupported to the depth of total scour (long-term plus contraction plus amended local abutment) for the design discharge. The calculations indicate that the depth of total scour will not expose the piles at Abutment No. 1 for the 100-year design discharge. As stated above, the base of Abutment No. 2 is elevated well above the 500-year flood elevation and should not be susceptible to scour.

"Superflood"

Page 2.4 of HEC-18 recommends that the foundation design should be checked for scour conditions resulting from a "Superflood". The design "should have a minimum factor of safety of 1.0 (ultimate load) under the superflood conditions." For this bridge, the 500-year flood was assumed to be the "Superflood". The scour computations indicate that at Abutment No. 1 the "Superflood" will not expose the piles, as with the 100-year design discharge. For Abutment No. 2, the foundation should not be susceptible to scour because the base is elevated above the 500-year flood height.

Figure 5. Scour Depth Cross Sections

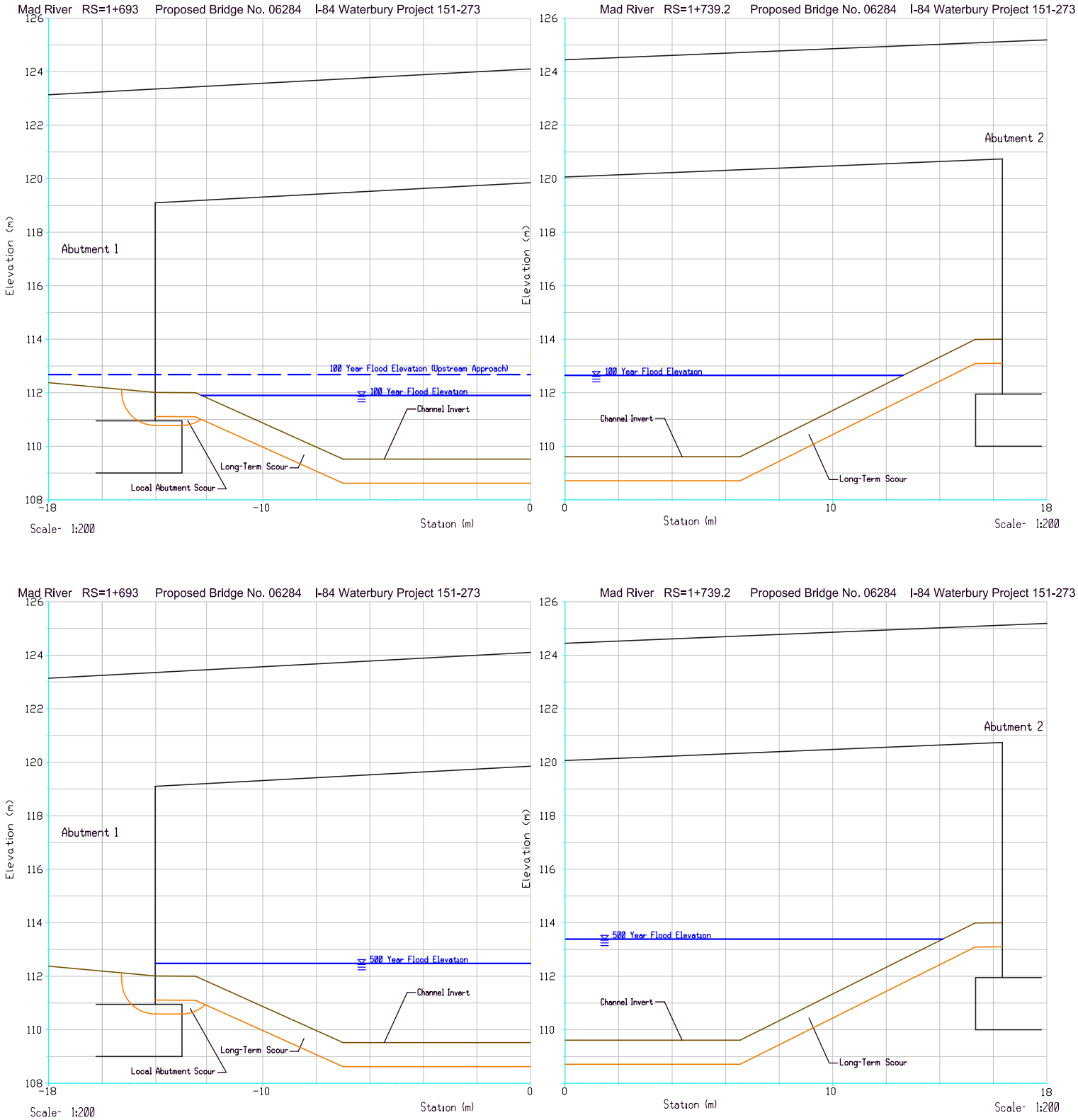
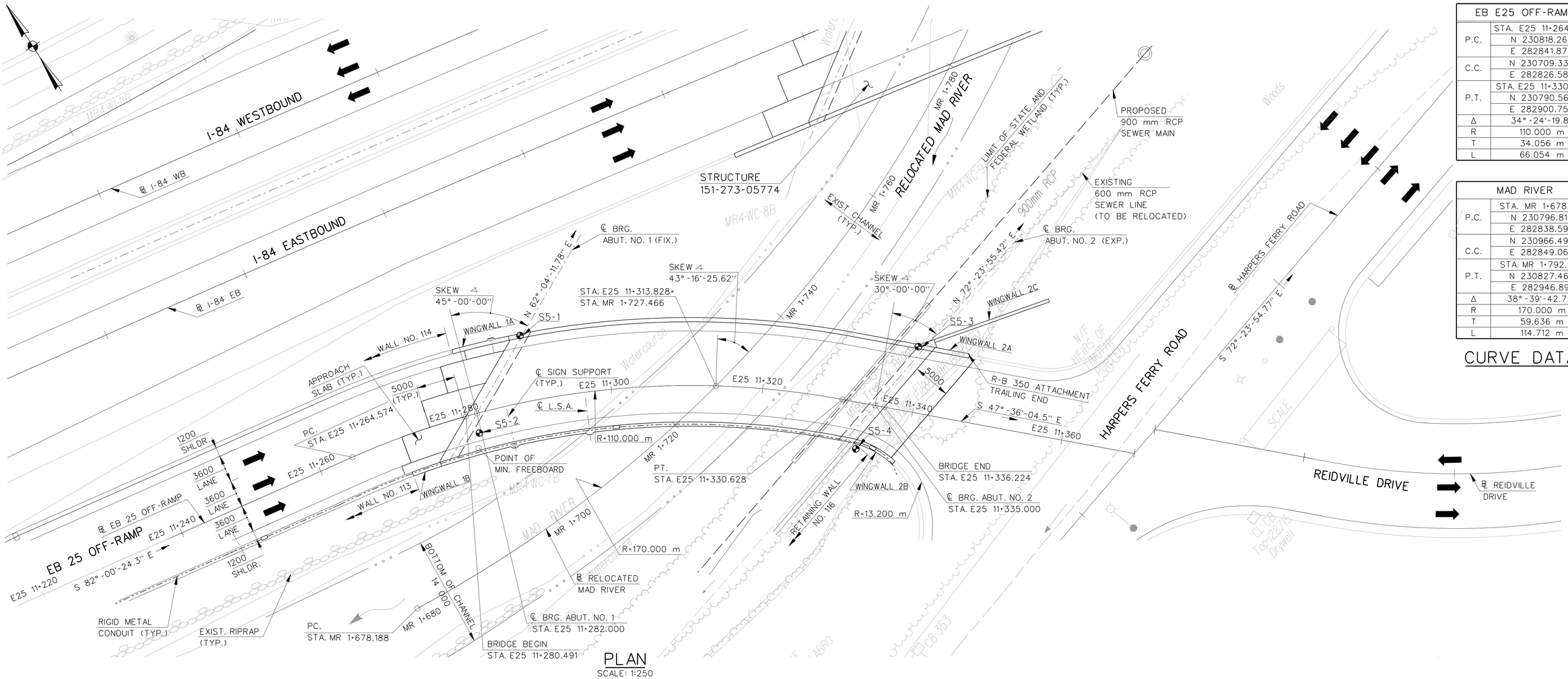


FIGURE 5

Appendix A: Structure Plans & Details

(Note: The plans and details included in this report are intended for information purposes only. If there are any discrepancies to the actual construction or "as-built" plans, the information reflected on the construction or "as-built" plans shall be construed more accurate.)

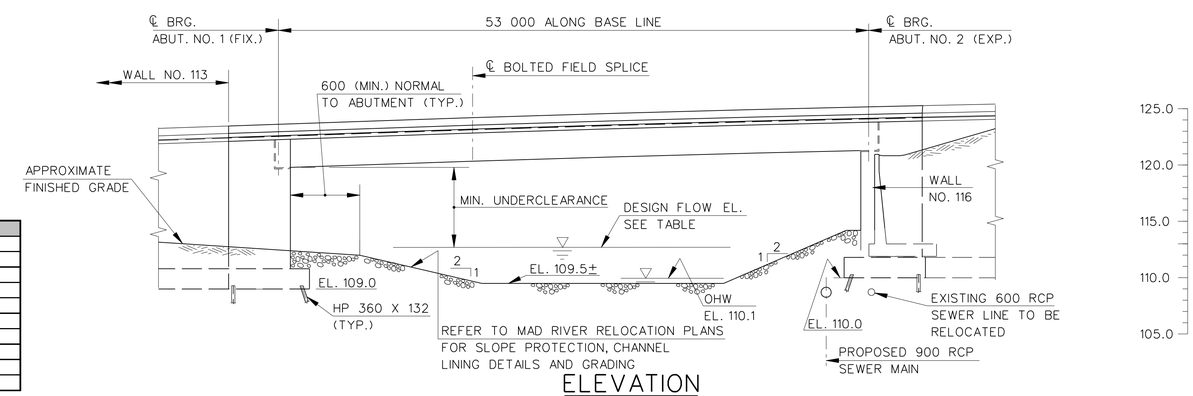


PLAN
SCALE: 1:250

EB E25 OFF-RAMP	
P.C.	STA. E25 11+264.574
	N 230818.265
	E 282841.877
C.C.	N 230709.334
	E 282826.580
P.T.	STA. E25 11+330.628
	N 230790.566
	E 282900.752
Δ	34°-24'-19.8"
R	110.000 m
T	34.056 m
L	66.054 m

MAD RIVER	
P.C.	STA. MR 1+678.188
	N 230796.817
	E 282838.595
C.C.	N 230966.495
	E 282849.062
P.T.	STA. MR 1+792.900
	N 230827.464
	E 282946.891
Δ	38°-39'-42.75"
R	170.000 m
T	59.636 m
L	114.712 m

CURVE DATA



ELEVATION
SCALE: 1:250

TRANSPORTATION DIMENSION AND MASS				
MEMBER	SHIPPING LENGTH	SHIPPING HEIGHT	SHIPPING WIDTH	SHIPPING MASS
G1	35 500	2590	2192	39 450 kg

BRIDGE/CULVERT NO.	06284
Drainage Area, km2	62.3
Design Frequency, year	100
Design Discharge, cms	176.98
Average Daily Flow Elevation, M	110.1 (observed)
Upstream Design Water Surface Elevation, M	112.68
Downstream Design Water Surface Elevation, M	112.60
Maximum Scour Elevation, M	110.59
Frequency (year)	500
Discharge (cms)	269.01
Worst case scour sub-strucutre unit	Abutment #1 (West)

BORING LEGEND

- 2001 BORING

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

SCALE AS NOTED

DESIGNER: C. ADAMS
DRAFTER: M. MOSLEY
CHECKED BY: B. YIN
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\STR5\FD\0273f05001.brg
PLOTTED 5/21/2014

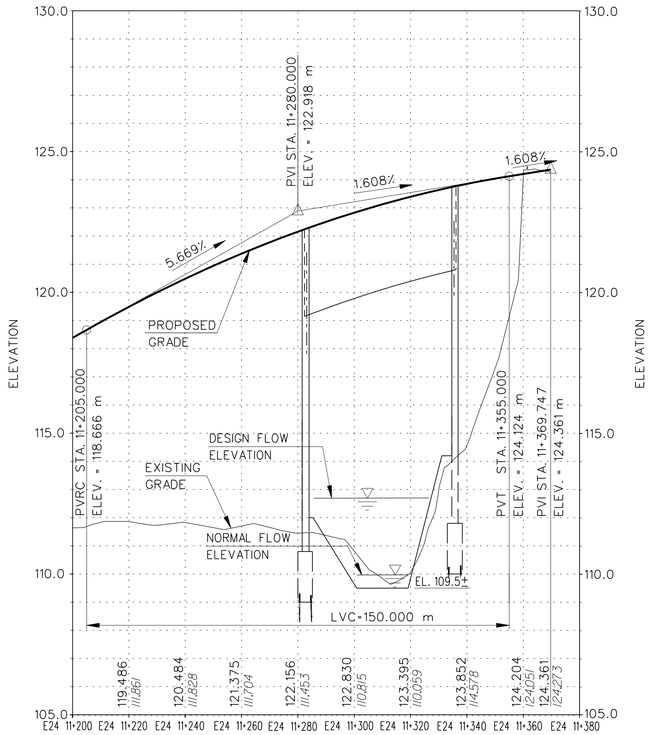
AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

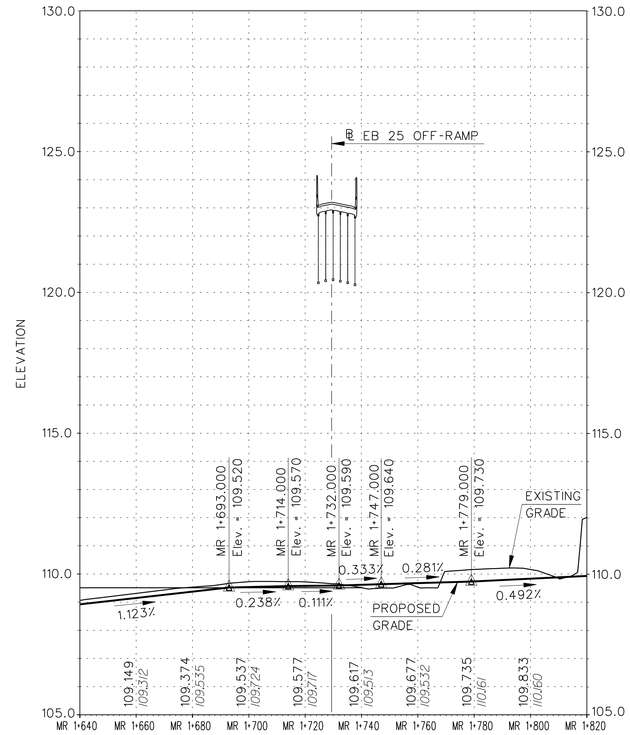
PROJECT TITLE:
RECONSTRUCTION OF I-84 WATERBURY
EB 25 OFF-RAMP OVER RELOCATED MAD RIVER
STRUCTURE NO. 151-273-06284

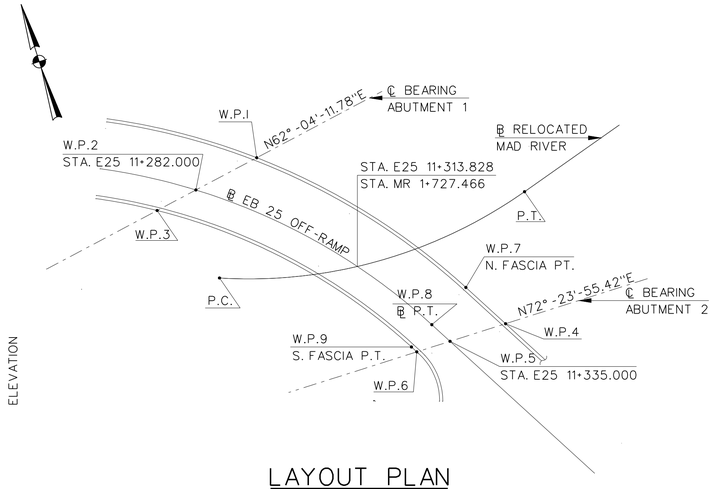
TOWN: WATERBURY

DRAWING TITLE: GENERAL PLAN AND ELEVATION

PROJECT NO.: 151-273
DRAWING NO.: S1
SHEET NO.: 05.04.001







LAYOUT PLAN

N.T.S.

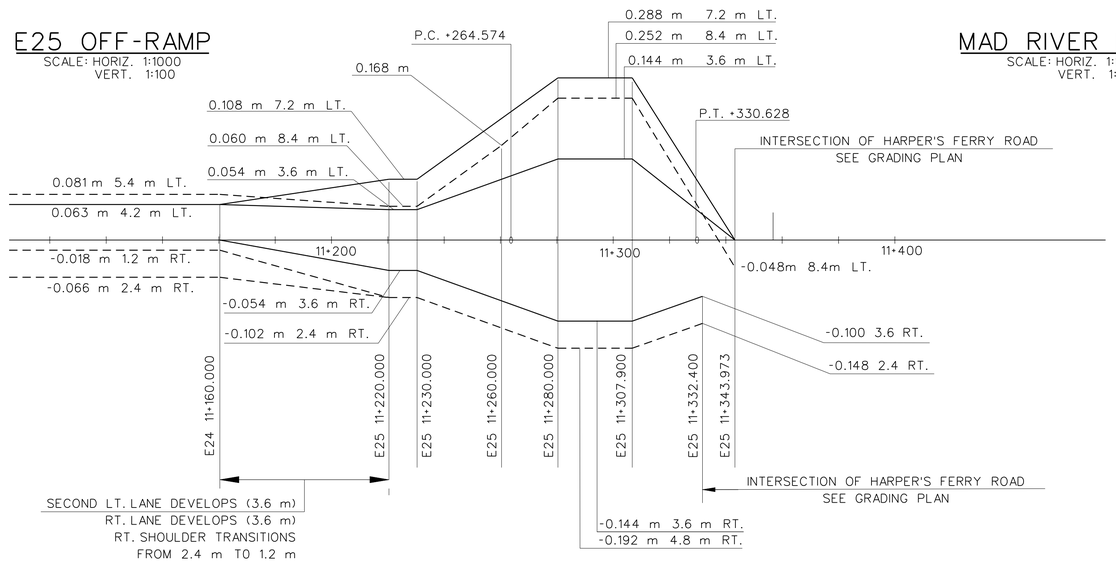
GIRDER COORDINATES

GIRDER ID	C.L. BRGS. ABUTMENT 1		C.L. BRGS. ABUTMENT 2	
	NORTH	EAST	NORTH	EAST
G- 1	230819.7122	282868.7234	230790.4634	282912.9506
G- 2	230818.1181	282865.7166	230789.5765	282910.1550
G- 3	230816.4948	282862.6546	230788.6896	282907.3593
G- 4	230814.8383	282859.5300	230787.8027	282904.5637
G- 5	230813.1440	282856.3340	230786.9158	282901.7681
G- 6	230811.4061	282853.0558	230786.0289	282898.9724

WORKING POINT NO.	NORTH	EAST
W.P. 1	230820.2149	282869.6717
W.P. 2	230814.4881	282858.8693
W.P. 3	230810.8416	282851.9910
W.P. 4	230790.7462	282913.8421
W.P. 5	230787.6176	282903.9804
W.P. 6	230785.7461	282898.0809
W.P. 7	230797.1822	282906.7935
W.P. 8	230790.5655	282900.7519
W.P. 9	230786.6073	282897.1377

E25 OFF-RAMP

SCALE: HORIZ. 1:1000
VERT. 1:100



MAD RIVER PROFILE

SCALE: HORIZ. 1:1000
VERT. 1:100

SUPERELEVATION DIAGRAM EB 25 OFF RAMP

N.T.S.

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

SCALE AS NOTED

DESIGNER: C. ADAMS
DRAFTER: M. MOSLEY
CHECKED BY: A. WHEELER
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\STR5\FD\0273f05005.brg
PLOTTED 4/2/2014

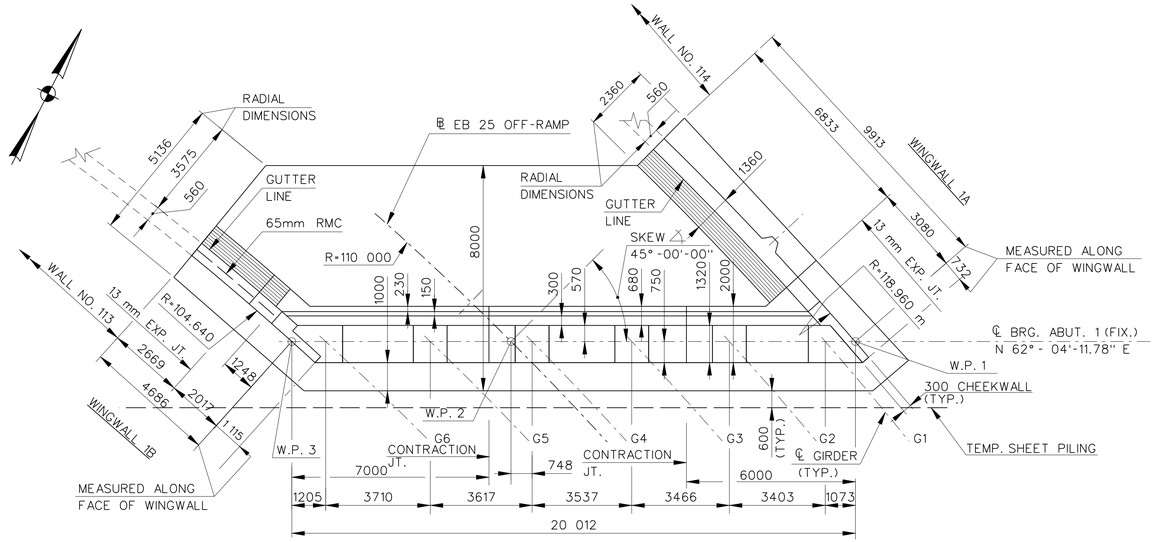
AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

PROJECT TITLE:
RECONSTRUCTION OF I-84 WATERBURY
EB 25 OFF-RAMP OVER RELOCATED MAD RIVER
STRUCTURE NO. 151-273-06284

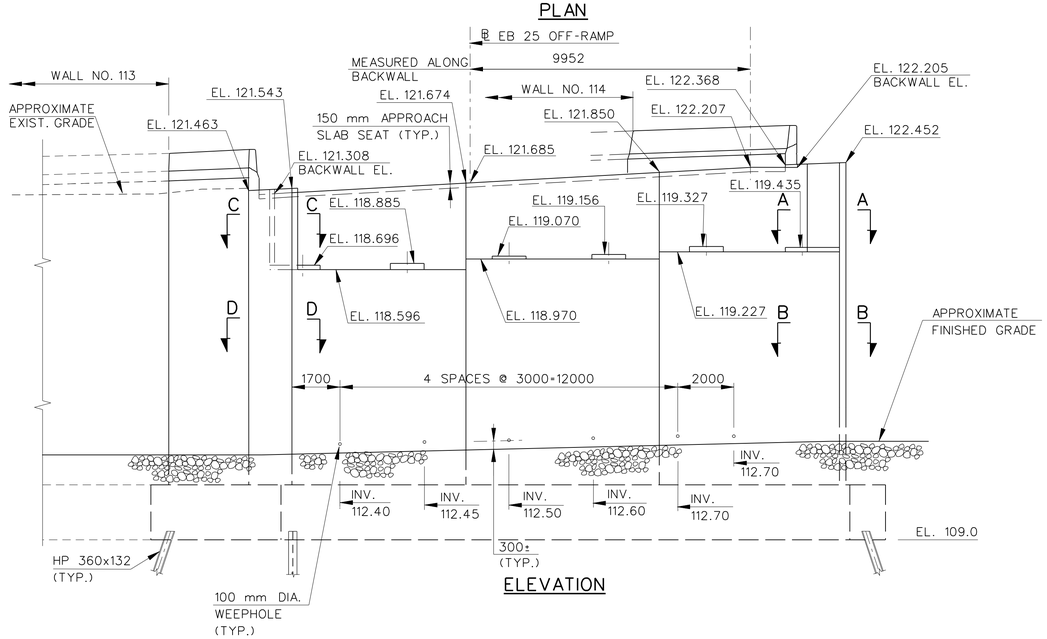
TOWN: WATERBURY

DRAWING TITLE:
PROFILES, LAYOUT PLAN
AND SUPERELEVATION

PROJECT NO.: 151-273
DRAWING NO.: S4
SHEET NO.: 05.04.004



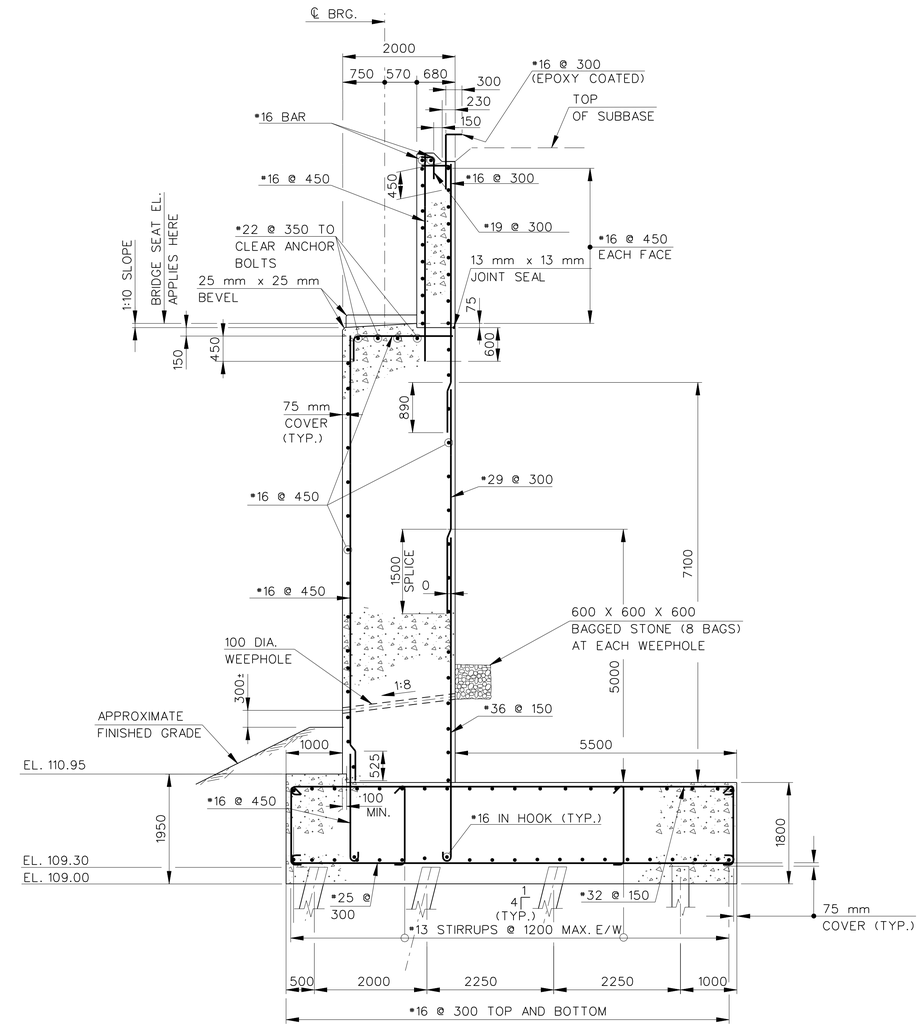
PLAN



ELEVATION

ABUTMENT 1

SCALE: 1:100



TYPICAL SECTION

SCALE: 1:50

NOTES

1. FOR PAY LIMITS OF TEMPORARY SHEET PILING, SEE STR. DWG. S12
2. FOR WORKING POINT (W.P.) COORDINATES, SEE STR. DWG. S4
3. FOR WINGWALL ELEVATIONS, SEE STR. DWG. S13
4. FOR CONCRETE PAD DETAILS, SEE STR. DWG. S15
5. FOR SECTIONS "A-A", "B-B", "C-C" AND "D-D", SEE STR. DWG. S14

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

SCALE AS NOTED

DESIGNER: A. WHEELER
DRAFTER: M. MOSLEY
CHECKED BY: C. ADAMS
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\str5\fd\0273I05010.brg
PLOTTED 4/2/2014

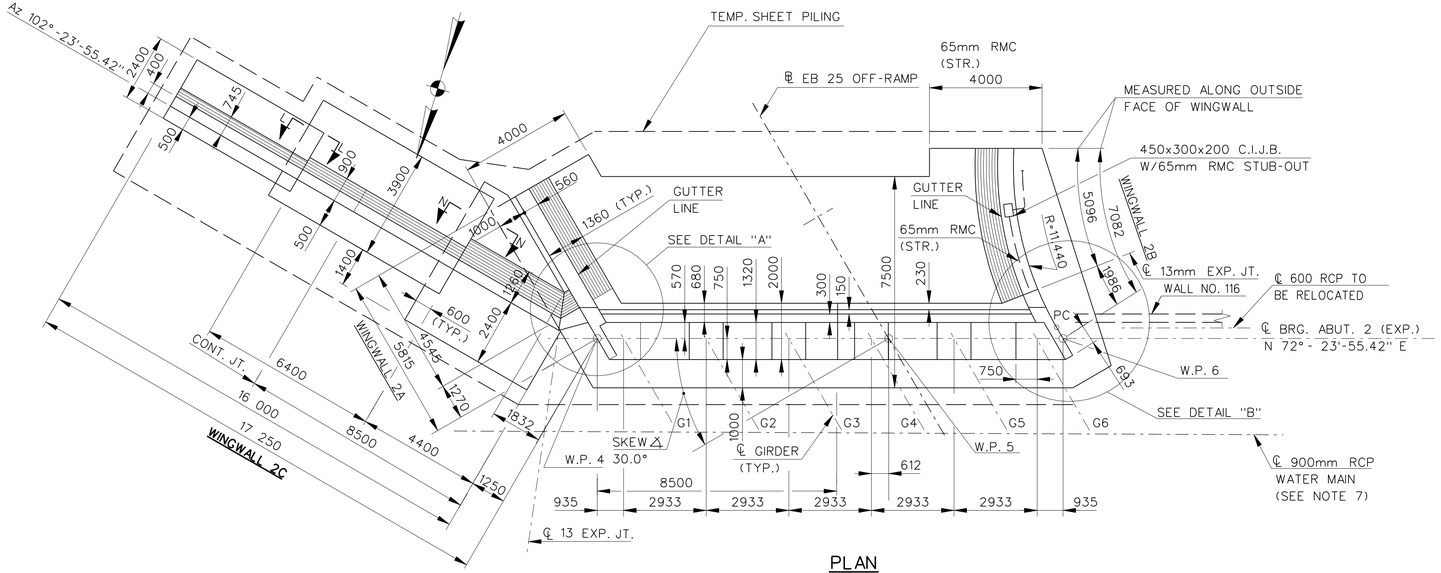
AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

PROJECT TITLE:
RECONSTRUCTION OF I-84 WATERBURY
EB 25 OFF-RAMP OVER RELOCATED MAD RIVER
STRUCTURE NO. 151-273-06284

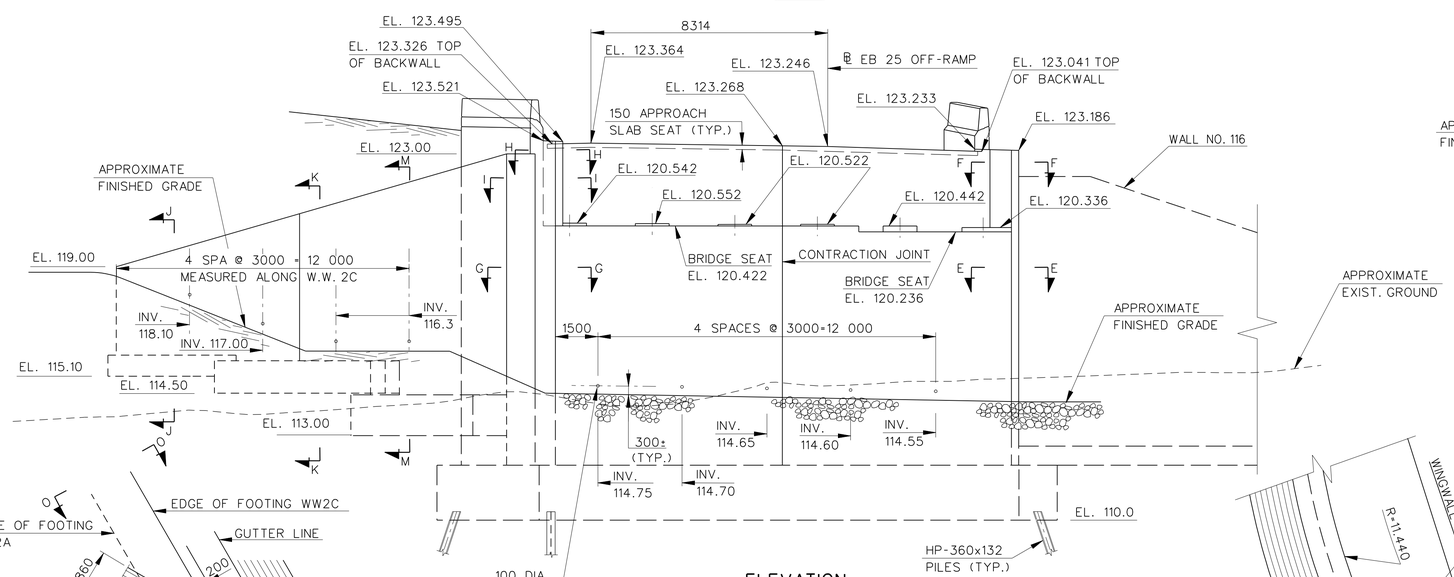
TOWN: WATERBURY

DRAWING TITLE: ABUTMENT 1 – PLAN, ELEVATION AND SECTION

PROJECT NO.: 151-273
DRAWING NO.: S10
SHEET NO.: 05.04.010



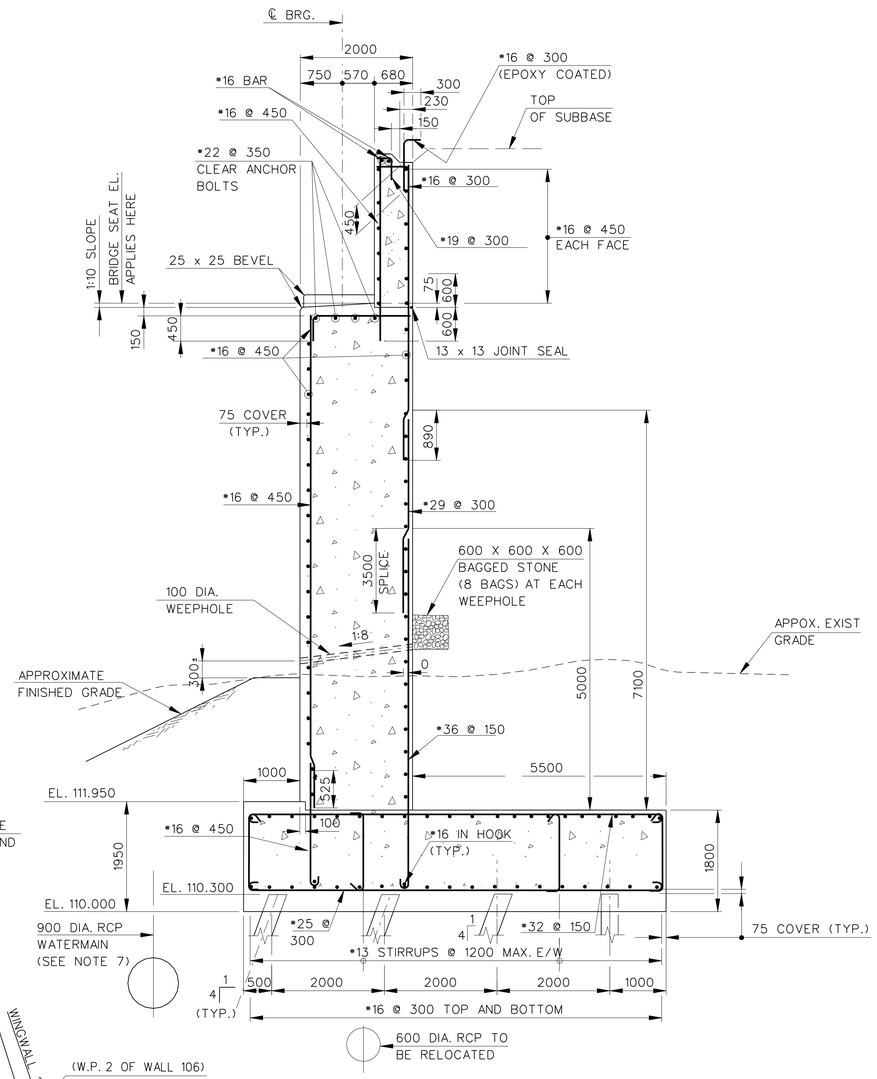
PLAN



ELEVATION

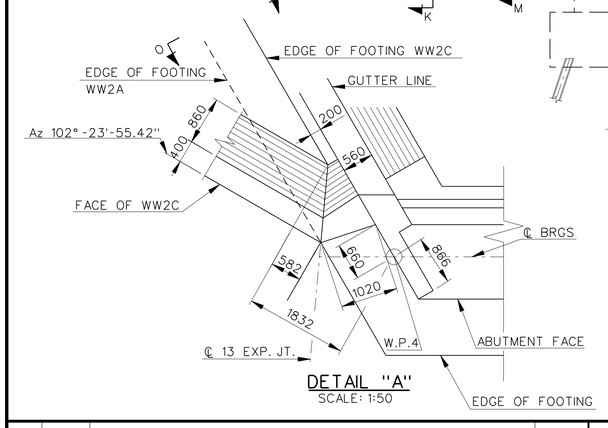
ABUTMENT 2

SCALE: 1:100



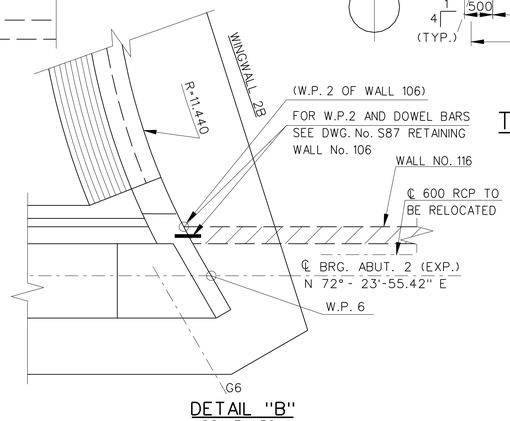
TYPICAL SECTION

SCALE: 1:50



DETAIL "A"

SCALE: 1:50



DETAIL "B"

SCALE: 1:50

NOTES

1. FOR PAY LIMITS OF TEMPORARY SHEET PILING, SEE STR. DWG. S12.
2. FOR WORKING POINT (W.P.) COORDINATES, SEE STR. DWG. S4.
3. FOR WINGWALL ELEVATIONS, SEE STR. DWG. S13
4. FOR CONCRETE PAD DETAILS, SEE STR. DWG. S15
5. FOR SECTIONS "E-E" THROUGH "I-I"SEE STR. DWG. S14
6. FOR WINGWALL 2C DETAILS AND SECTIONS "J-J" THROUGH "O-O", SEE STR. DWG. S15
7. CONTRACTOR TO VERIFY LOCATION OF 900mm RCP WATER MAIN , PRIOR TO THE CONSTRUCTION OF THE ABUTMENT.

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

SCALE AS NOTED

DESIGNER: A. WHEELER
DRAFTER: M. MOSLEY
CHECKED BY: C. ADAMS
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\str5\fd\0273f05012.brg
PLOTTED 4/2/2014

AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

PROJECT TITLE:
RECONSTRUCTION OF I-84 WATERBURY
EB 25 OFF-RAMP OVER RELOCATED MAD RIVER
STRUCTURE NO. 151-273-06284

TOWN: WATERBURY

DRAWING TITLE: ABUTMENT 2 – PLAN, ELEVATION AND SECTIONS

PROJECT NO.: 151-273
DRAWING NO.: S11
SHEET NO.: 05.04.011

Appendix B: Scour Computations

Based on DOT Design Discharges

- Summary Sheet
- 100-YR Contraction Scour
- 100-YR Abutment Scour
- 500-YR Contraction Scour
- 500-YR Abutment Scour

Final Design

Bridge No. 06284

Eastbound Exit 24 Off-Ramp to Harpers Ferry Road

Computed Scour Depths using Froehlich's Abutment Scour Equation

July 2006 - Revised March 2014

Abutment #1- Westerly Abutment or Left Abutment Looking Upstream

Flood Recurrence	Ave. Flow Depth Obstructed	Scour Depth (m)				
		Long-Term	Contraction	Abutment Equation	Amended Abutment	Amended Total
Q_{100}	0.28	0.9	0.00	Froehlich	0.32	1.22
Q_{500}	0.86	0.9	0.00	Froehlich	0.51	1.41
Overtopping	> Q_{500}					

Abutment #2- Easterly Abutment or Right Abutment Looking Upstream

Flood Recurrence	Ave. Flow Depth Obstructed	Scour Depth (m)				
		Long-Term	Contraction	Abutment Equation	Amended Abutment	Amended Total
Q_{100}	0.00	0.9	0.00	N/A	0.00	0.90
Q_{500}	0.00	0.9	0.00	N/A	0.00	0.90
Overtopping	> Q_{500}					

Comparison of Footing Elevations to Computed Scour Depths

Abutment No.	Depth of Footing (m)	Elevation (m)		Assumed Ground Elevation at Base of Abutment	Elevation of Scour at Abutment (m)			
					100 Year Discharge		500 Year Discharge	
		Top of Footing	Bottom of Footing		Long-Term + Contraction	Total	Long-Term + Contraction	Total
1	1.95	110.95	109.00	112.00	111.10	110.78	111.10	110.59
2	1.95	111.95	110.00	114.00	113.10	113.10	113.10	113.10

Abutment No. 1

-Top of footing below the sum of long-term channel degradation and contraction scour depths for the 100 year discharge- Design OK

-Computed total scour depth for the 100 year discharge is above the bottom of the footing, piles are not exposed by scour

-Computed total scour depth for the 500 year discharge is above the bottom of the footing, piles are not exposed by scour

Abutment No. 2

-Top of footing below the sum of long-term channel degradation and contraction scour depths for the 100 year discharge- Design OK

-Computed total scour depth for the 100 year discharge is above the bottom of the footing, piles are not exposed by scour

-Computed total scour depth for the 500 year discharge is above the bottom of the footing, piles are not exposed by scour

PROJECT NO. 151-273 **BRIDGE NO.** 06284 **UNIT:** Metric

Ref. HEC-18., May 2001 (4th ed.)

SUMMARY

Contraction Scour		Type:	**LIVE-BED**	Depth:	**0.00** m	Event:	**100-YR**
Local	**West Abut. #1**	**LEFT**	Eq.: Froehlich	Depth:	**0.32** m	Event:	**100-YR**
Abutment	**East Abut. #2**	**RIGHT**	Eq.: N/A	Depth:	**N/A** m	Event:	**100-YR**

CONTRACTION SCOUR

$V_c = K_u y^{1/6} D^{1/3}$ .....Eq. 5.1

= 0.50 *m/s* Critacal velocity above which bed material of size D and smaller will be transported

Ku = 6.19 m (6.19 in SI units; 11.17 in English units)

y = 2.32 m Average depth of flow upstream of the bridge

D = 0.00034 m Particle size for Vc *, m* (use D_{50})

V1 = 3.01 *m/s* The mean velocity of the flow in the main channel or overbank area upstream of the brige opening

Vc < V1 ***Thus, LIVE-BED CONTRACTION SCOUR***

Live-Bed Contraction Scour ==========

$Y_2/Y_1 = (Q_2/Q_1)^{6/7} (W_1/W_2)^{k_1}$ = 1.02 .....Eq. 5.2

$Y_s = Y_2 - Y_o$ m .....Eq. 5.3

= -0.06 m Average contraction scour depth

Y_1 = 2.32 m Average depth in the upstream main channel

Y_2 = 2.36 m Average depth in the contracted section

Y_o = 2.42 m Existing depth in the contracted section before scour

Q_1 = 176.98 m3/s Flow in the upstream channel transporting sediment

Q_2 = 176.57 m3/s Flow in the contracted channel

W_1 = 24.93 m Bottom width of the upstream main channel that is transporting bed material

W_2 = 24.24 m Bottom width of the main channel in the contracted section less pier width

k_1 = 0.69 Exponent determined below (V^*/ω = 8.31)

V^* = 0.4155 $=(T_o/\rho)^{1/2}$ or $(gY1\ S1)^{1/2}$, shear velocity in the upstream section , m/s

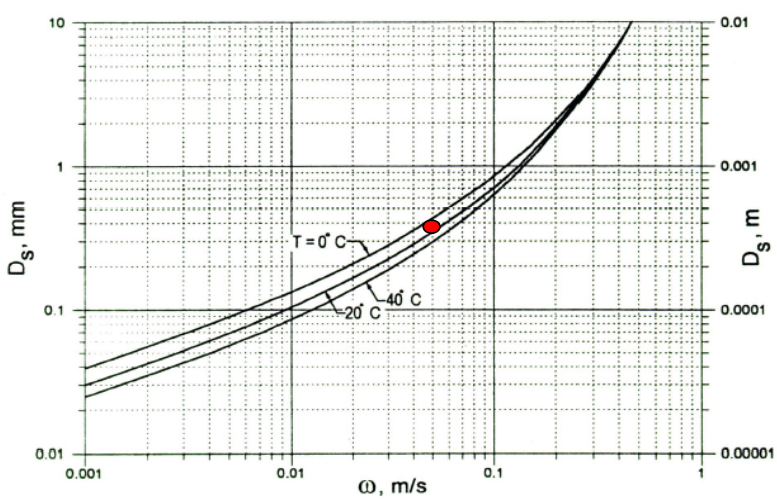
ω = 0.05 m/s Fall velocity of bed material based on the D_{50} (Figure 5.8)

g = 9.81 m/s^2 Acceleration of gravity

S1 = 0.007587 m/m Slope of energy gradeline of main channel

T_o = 107.48 Pa (N/m^2) Shear stess on the bed

ρ = 1000 kg/m^3 Density of water



V^*/ω	k1	*Mode of Bed Material Transport*
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

Figure 5.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Clear-Water Contraction Scour ==========

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2} \right]^{3/7}$$ .....Eq. 5.4

$$y_s = y_2 - y_o \quad m$$ .....Eq. 5.5

=	N/A	m	Average contraction scour depth **LIVE-BED controls. Ignore this procedure**
y_2 =	10.39	m	Average equilibrium depth in the contracted section after contraction scour
y_o =	2.42	m	Average existing depth in the contracted section
Q =	176.98	m3/s	Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W
W =	24.24	m	Bottom width of the contracted section less pier widths
K_u =	0.0250		(0.025 in SI units; 0.0077 in English units)
D_m =	0.0004	m	Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in th contacted setion
D_{50} =	0.0003	m	Median diameter of bed material

Because D_{50} is not the largest particle in the bed material, the scoured section can be slightly armored. Therefore, the D_m is assumed to be 1.25 D_{50}. For stratified bed material the depth of scour can be determined by using the clear-water scour equation sequentially with successive D_m of the bed material layers.

Data Source

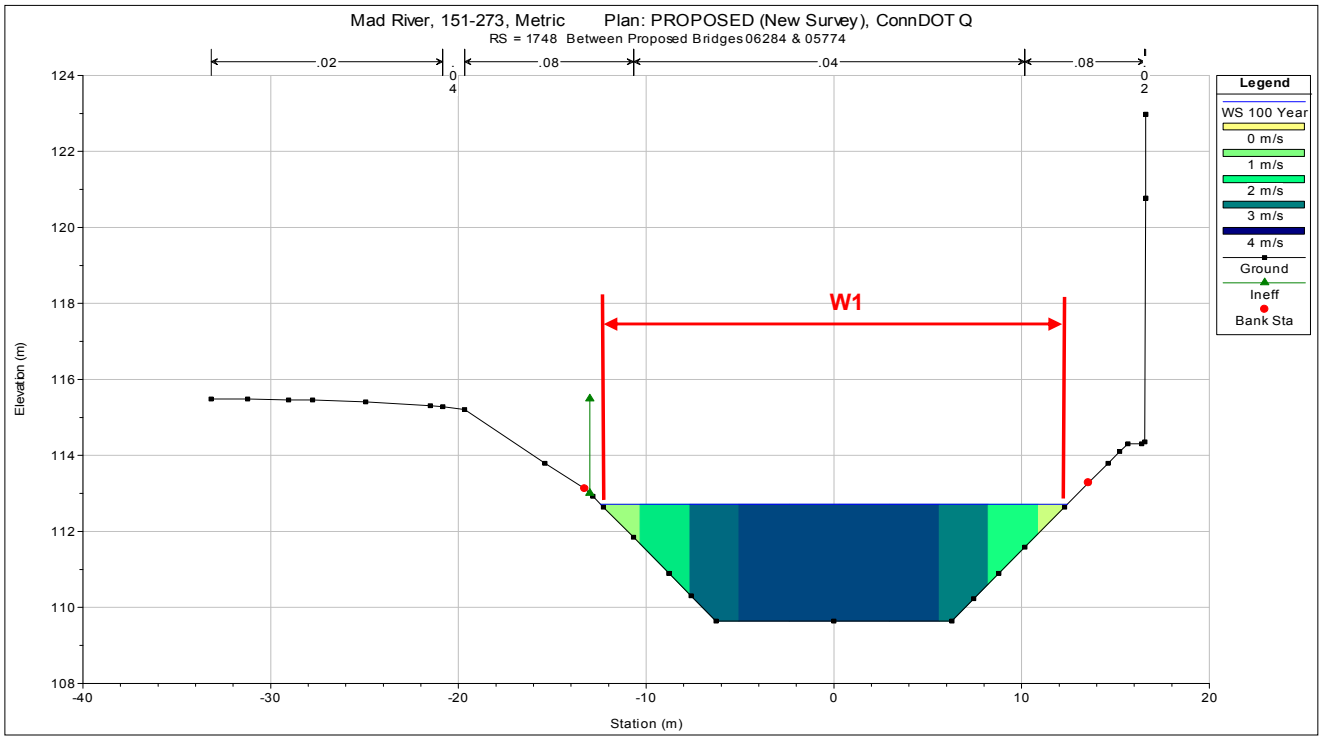
Eq. 5.1				From:	RS
y =	2.32	m		C	1748
V1 =	3.01	m		C	1727.5 BR U
Eq. 5.2 & 5.3					
Y1 =	2.32	m		C	1748
Yo =	2.42	m		C	1727.5 BR U
Q1 =	176.98	m3/s		C	1748
Q2 =	176.57	m3/s		C	1727.5 BR U
W1 =	24.93	m		C	1748
or	(n/a)	m (manual)			
W2 =	24.24	m		C	1727.5 BR U
or	(n/a)	m (manual)			
S1 =	0.007587	m/m		C	1748
To =	107.48	Pa (N/m^2)		C	1727.5 BR U
P2 =	0	m (pier width)			
Eq. 5.4 & 5.5					
Q =	176.98	m3/s		C	1727.5

Legends:

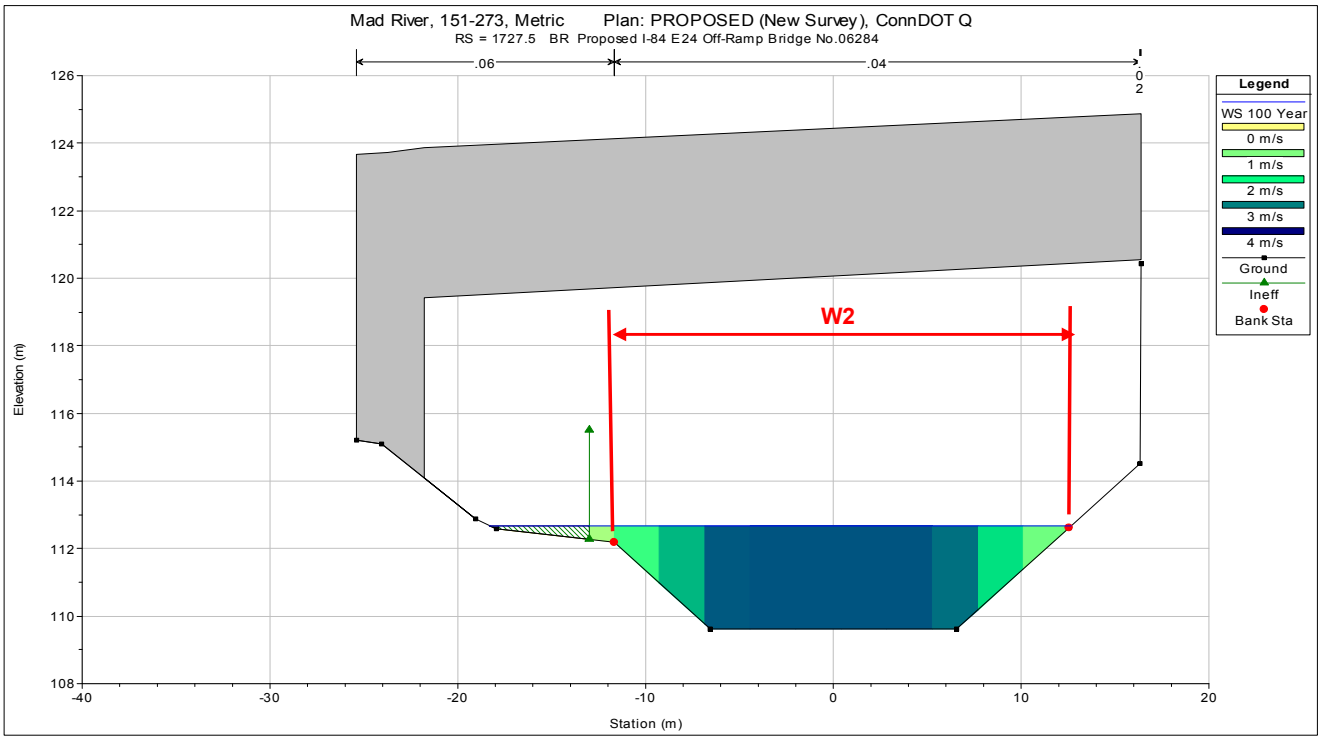
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections used for Constraction Scour Computations

UPSTREAM SECTION 1748



CONTRACTED SECTION 1727.5 BR U



UPSTREAM CHANNEL SECTION

River Station 1748 Event: 100-YR

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1748 Profile: 100 Year

E.G. Elev (m)	113.2	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.48	Wt. n-Val.		0.048		
W.S. Elev (m)	112.72	Reach Len. (m)	9.4	9.4	9.4	
Crit W.S. (m)	112.02	Flow Area (m2)		57.82		
E.G. Slope (m/m)	0.007587	Area (m2)		57.82		57.82
Q Total (m3/s)	176.98	Flow (m3/s)		176.98		
Top Width (m)	24.93	Top Width (m)		24.93		
Vel Total (m/s)	3.06	Avg. Vel. (m/s)		3.06		
Max Chl Dpth (m)	3.08	Hydr. Depth (m)		2.32		2.32
Conv. Total (m3/s)	2031.8	Conv. (m3/s)		2031.8		
Length Wtd. (m)	9.4	Wetted Per. (m)		26.39		
Min Ch El (m)	109.64	Shear (N/m2)		163.05		
Alpha	1	Stream Power (N/m s)	795.26	0	0	
Frctn Loss (m)	0.06	Cum Volume (1000 m3)	9.8	54.48	4.21	
C & E Loss (m)	0.01	Cum SA (1000 m2)	23.42	23.3	6.42	

	Flow dis.	*manual*
Left WS Sta.	-13	-12.46
Left Convy Sta.	-13	-12.46
Left Main Channel	-12.46	
Right Main Channel	12.47	
Right Convy Sta.	13.86	12.47
Right WS Sta.		12.47

L' (left)	0	L (left)	0
L' (Right)	0	L (Right)	0

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT					
Main	24.93	176.99	57.81	2.32	3.06
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1748 Profile: 100 Year

Pos		Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	Chan	-13	-10.34	0.84	1.12	2.37	0.48	0.53	0.75	35.26	26.46
2	Chan	-10.34	-7.69	9.92	4.57	2.97	5.6	1.72	2.17	114.65	248.67
3	Chan	-7.69	-5.03	24.43	7.7	2.82	13.81	2.9	3.17	202.91	643.91
4	Chan	-5.03	-2.38	28.22	8.19	2.66	15.94	3.08	3.44	229.48	790.49
5	Chan	-2.38	0.28	28.22	8.19	2.66	15.94	3.08	3.44	229.48	790.49
6	Chan	0.28	2.94	28.22	8.19	2.66	15.94	3.08	3.44	229.48	790.49
7	Chan	2.94	5.59	28.22	8.19	2.66	15.94	3.08	3.44	229.48	790.49
8	Chan	5.59	8.25	21.63	7.22	2.89	12.22	2.72	2.99	186	557
9	Chan	8.25	10.9	7.04	3.83	2.97	3.98	1.44	1.84	96.04	176.54
10	Chan	10.9	13.56	0.25	0.61	1.75	0.14	0.39	0.4	25.95	10.45
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CONTRACTED CHANNEL SECTION

River Station 1727.5 BR U

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 BR U Profile: 100 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	113.14	Element				
Vel Head (m)	0.46	Wt. n-Val.	0.06	0.04	0.04	
W.S. Elev (m)	112.68	Reach Len. (m)	19.7	19.7	19.7	
Crit W.S. (m)	111.95	Flow Area (m2)	0.6	58.73	0	
E.G. Slope (m/m)	0.004769	Area (m2)	1.89	58.73	0	60.62
Q Total (m3/s)	176.98	Flow (m3/s)	0.41	176.57	0	
Top Width (m)	31.01	Top Width (m)	6.64	24.24	0.14	
Vel Total (m/s)	2.98	Avg. Vel. (m/s)	0.68	3.01	0.17	
Max Chl Dpth (m)	3.07	Hydr. Depth (m)	0.46	2.42	0.03	1.95
Conv. Total (m3/s)	2562.7	Conv. (m3/s)	5.9	2556.8	0	
Length Wtd. (m)	19.7	Wetted Per. (m)	1.31	25.55	0.15	
Min Ch El (m)	109.61	Shear (N/m2)	21.27	107.48	1.42	
Alpha	1.01	Stream Power (N/m s)	784.24	0	0	
Frctn Loss (m)	0.09	Cum Volume (1000 m3)	9.8	53.93	4.21	
C & E Loss (m)	0.01	Cum SA (1000 m2)	23.39	23.07	6.42	

	Flow dis.	*manual*
Left WS Sta.	-18.51	-18.33
Left Flood Sta.	-13	-13
Left Main Channel	-11.69	
Right Main Channel	12.63	
Right Flood Sta.	12.55	12.69
Right WS Sta.		12.69
L' (left) 1.31	L (left)	6.64
L' (Right) 0.06	L (Right)	0.06

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		0.41	1.89		
Main	24.32	176.58	58.73	2.41	3.01
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 BR U Profile: 100 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-18.51	-17.13	0	0.12	1.21	0	0.1	0	4.7	0
2	LOB	-17.13	-15.75	0	0.27	1.38	0	0.19	0	9.1	0
3	LOB	-15.75	-14.38	0	0.39	1.38	0	0.28	0	13.19	0
4	LOB	-14.38	-13	0	0.51	1.38	0	0.37	0	17.28	0
5	LOB	-13	-11.69	0.41	0.6	1.31	0.23	0.46	0.68	21.27	14.48
6	Chan	-11.69	-9.27	4.19	2.67	2.71	2.37	1.1	1.57	46.13	72.3
7	Chan	-9.27	-6.84	14.39	5.6	2.71	8.13	2.31	2.57	96.75	248.45
8	Chan	-6.84	-4.42	24.46	7.41	2.46	13.82	3.06	3.3	140.96	465.19
9	Chan	-4.42	-1.99	24.83	7.44	2.42	14.03	3.07	3.34	143.47	479.04
10	Chan	-1.99	0.43	24.83	7.44	2.42	14.03	3.07	3.34	143.47	479.04
11	Chan	0.43	2.85	24.83	7.44	2.42	14.03	3.07	3.34	143.47	479.04
12	Chan	2.85	5.28	24.83	7.44	2.42	14.03	3.07	3.34	143.47	479.04
13	Chan	5.28	7.7	22.16	7.1	2.56	12.52	2.93	3.12	129.65	404.66
14	Chan	7.7	10.13	10.22	4.56	2.71	5.77	1.88	2.24	78.78	176.39
15	Chan	10.13	12.55	1.84	1.63	2.71	1.04	0.67	1.13	28.15	31.74
16	ROB	12.55	12.93	0	0	0.15	0	0.03	0.17	1.42	0.24
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LIVE SCOUR AT ABUTMENTS

Froehlich's Live-Bed Abutment Scour Equation — LEFT: RIGHT: ==========

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 1 =$ **2.09** **N/A** .....Eq. 7.1

Amended Local Scour Equation

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 0.05 =$ **1.14** **N/A** .....CT DOT DM Pg 9B-2

	LEFT	RIGHT		
Ys =	**0.32**	**N/A**	**m**	Scour depth <== using Amended equation
K_1 =	0.82	0.55		Coeffcient for abutment shape (see Table 7.1 and Figrue 7.6)
K_2 =	1.05	0.91		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
θ =	135	45		
				θ < 90 degrees if embankment points downstream
				θ > 90 degrees if embankment points upstream
				(see Figure 7.5 for definition of θ)
L' =	1.31	0.00	m	Length of active flow obstructed by the embankment (see Figure 7.4)
Ae =	1.89	0.00	m^2	Flow area of the approach cross section obstructed by the embankment
Fr =	0.13	N/A		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment
Ve =	0.22	N/A	m/s	Qe/Ae
Qe =	0.41	0	m^3/s	Flow obstructed by the abutment and approach embankment
Ya =	0.28	N/A	m	Ae/L, Average depth of flow on the floodplain
L =	6.64	0	m	Length of embankment projected normal to the flow

Table 7.1. Abutment Shape Coefficients.

Description	K_1
Vertical-wall abutment	1.00
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

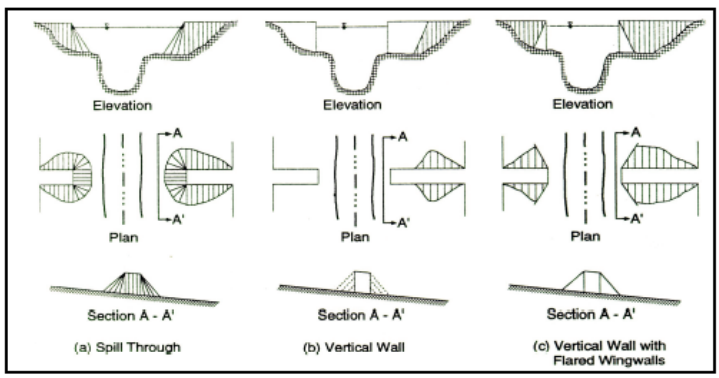


Figure 7.6. Abutment shape.

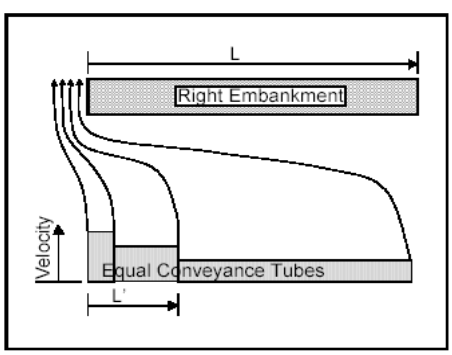


Figure 7.4. Determination of length of embankment blocking live flow for abutment scour estimation.

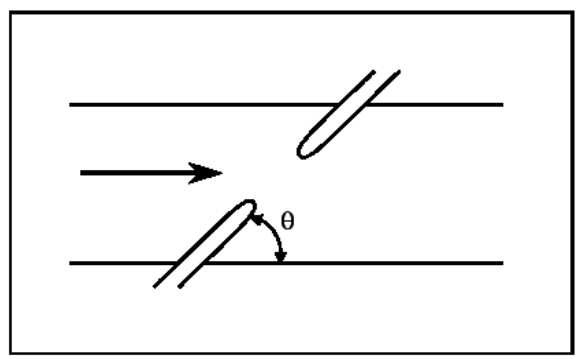


Figure 7.5. Orientation of embankment angle, θ, to the flow.

HIRE Live-Bed Abutment Scour Equation ==========

		LEFT	RIGHT	
Applicability check:	L/Y_1 =	3	N/A	*Use HIRE Eq. only if $L/Y_1 > 25$*
$Y_s/Y_1 = 4\ Fr^{0.33}\ K_1/0.55\ K_2$ =		**N/A**	**N/A**	.....Eq. 7.1

	LEFT	RIGHT		
Ys =	**N/A**	**N/A**	**m**	Scour depth (N/A if $L/Y_1 < 25$)
K1 =	0.82	0.55		Coeffcient for abutment shape (see Table 7.1 on RIGHT)
K2 =	1.05	0.91		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
Y1 =	2.32	N/A	m	Depth of flow at the abutment on the overbank or in the main channel,
Fr =	0.13	N/A		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment

Data Source

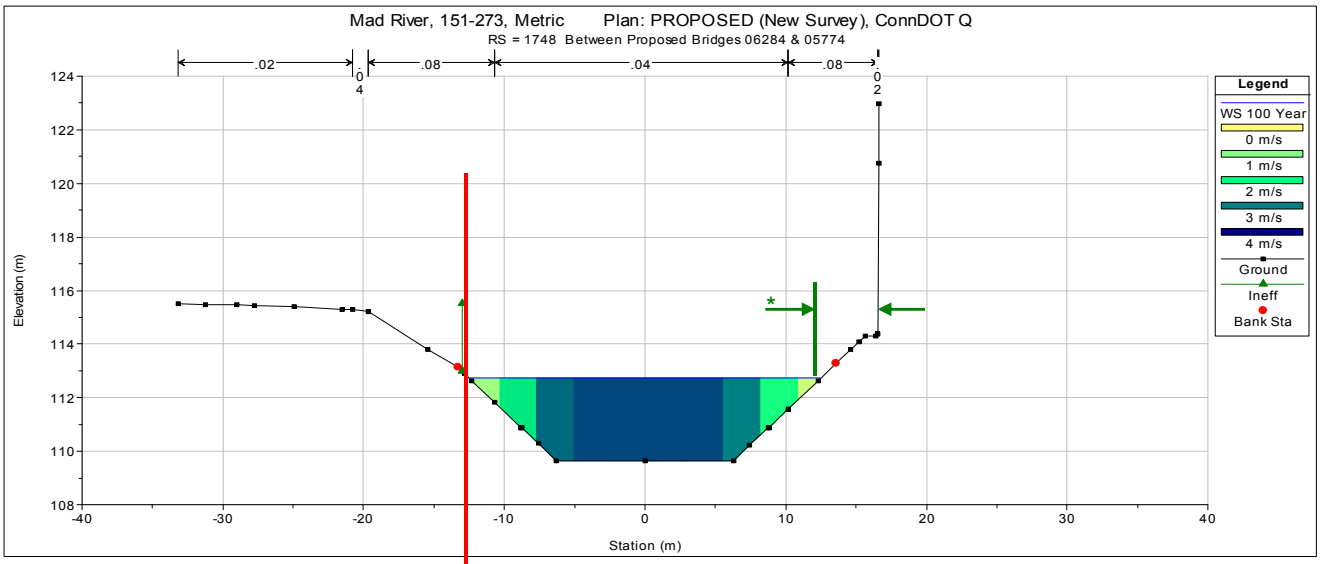
Eq. 7.1				From:	RS
LT				UF	
	L' =	1.31	m	D	1727.5 BR U
	Ae =	1.89	m2	D	1727.5 BR U
	Qe =	0.41	m3/s	D	1727.5 BR U
	L =	6.64	m	D	1727.5 BR U
RT				UC	
	L' =	0	m	D	1748
	Ae =	0	m2	D	1748
	Qe =	0	m3/s	D	1748
	L =	0	m	D	1748

Legends:

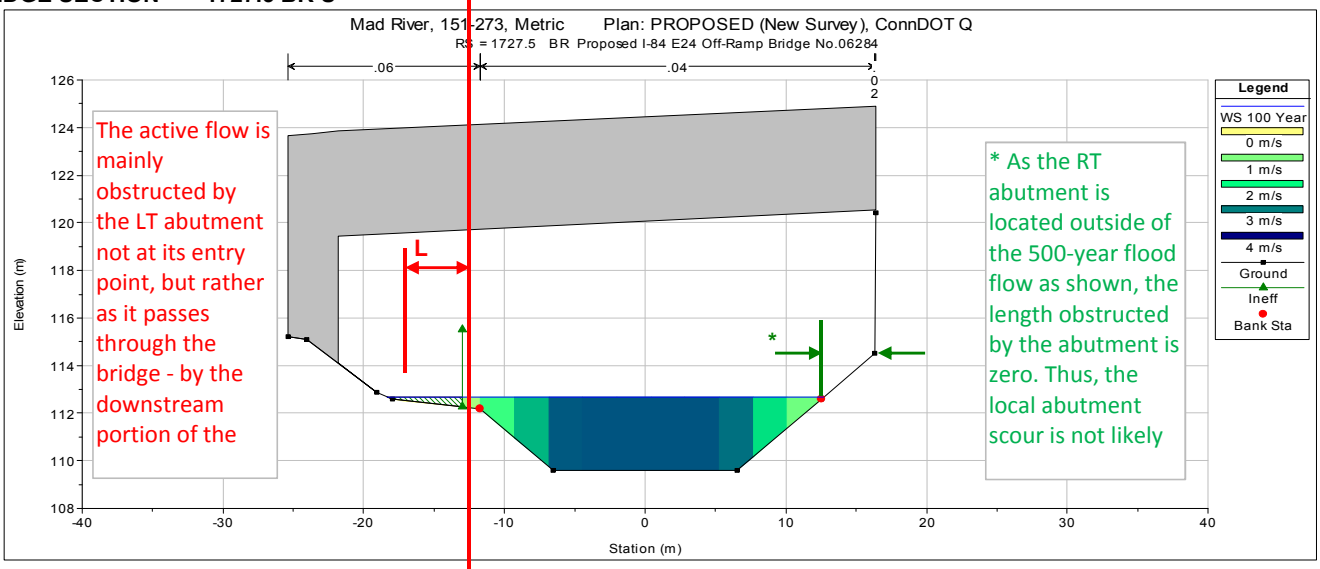
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections Used for Local Abutment Scour Computations

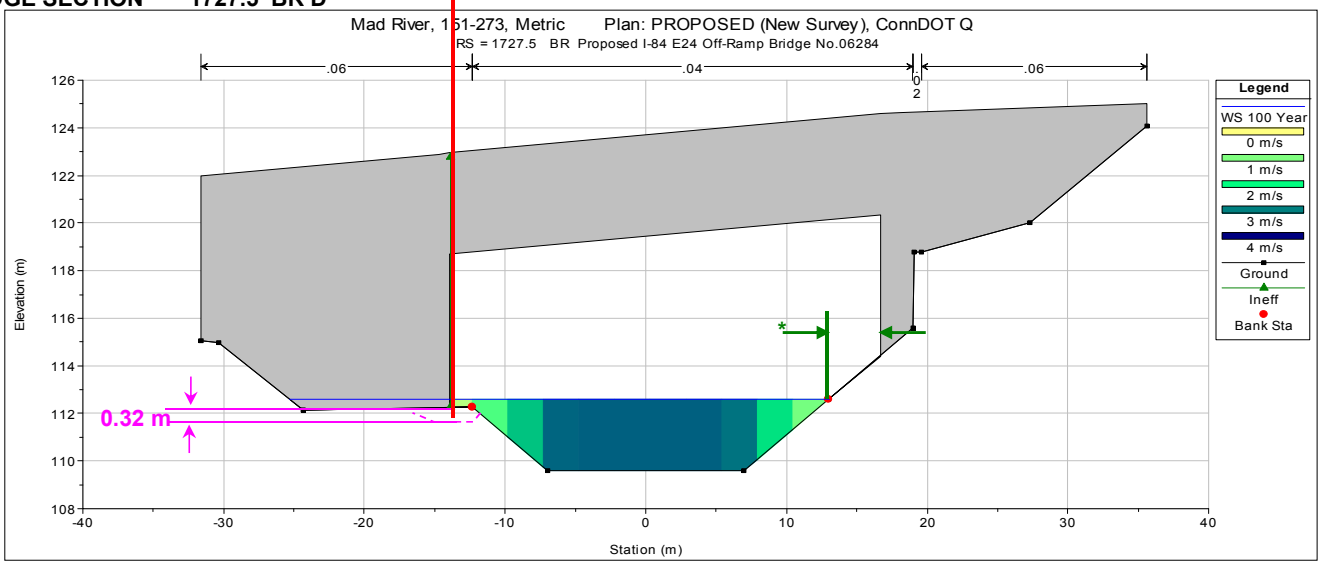
APPROACH SECTION 1748



BRIDGE SECTION 1727.5 BR U



BRIDGE SECTION 1727.5 BR D



UPSTREAM APPROACH CHANNEL SECTION

River Station 1748 Event: 100-YR

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computation?*** No

Plan: PR_DOT Mad River Reach 1 RS: 1748 Profile: 100 Year

E.G. Elev (m)	113.2	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.48	Wt. n-Val.		0.048		
W.S. Elev (m)	112.72	Reach Len. (m)	9.4	9.4	9.4	
Crit W.S. (m)	112.02	Flow Area (m2)		57.82		
E.G. Slope (m/m)	0.007587	Area (m2)		57.82		57.82
Q Total (m3/s)	176.98	Flow (m3/s)		176.98		
Top Width (m)	24.93	Top Width (m)		24.93		
Vel Total (m/s)	3.06	Avg. Vel. (m/s)		3.06		
Max Chl Dpth (m)	3.08	Hydr. Depth (m)		2.32		2.32
Conv. Total (m3/s)	2031.8	Conv. (m3/s)		2031.8		
Length Wtd. (m)	9.4	Wetted Per. (m)		26.39		
Min Ch El (m)	109.64	Shear (N/m2)		163.05		
Alpha	1	Stream Power (N/m s)	795.26	0	0	
Frctn Loss (m)	0.06	Cum Volume (1000 m3)	9.8	54.48	4.21	
C & E Loss (m)	0.01	Cum SA (1000 m2)	23.42	23.3	6.42	

		Flow dis.	*manual*
Left WS Sta.		-13	-12.46
Left Flood Sta.		-13	-12.46
Left Main Channel		-12.46	
Right Main Channel		12.47	
Right Flood Sta.		13.86	12.47
Right WS Sta.			12.47
L' (left)	0	L (left)	0
L' (Right)	0	L (Right)	0

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT					
Main	24.93	176.99	57.81	2.32	83.46
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1748 Profile: 100 Year

Pos		Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	Chan	-13	-10.34	0.84	1.12	2.37	0.48	0.53	0.75	35.26	26.46
2	Chan	-10.34	-7.69	9.92	4.57	2.97	5.6	1.72	2.17	114.65	248.67
3	Chan	-7.69	-5.03	24.43	7.7	2.82	13.81	2.9	3.17	202.91	643.91
4	Chan	-5.03	-2.38	28.22	8.19	2.66	15.94	3.08	3.44	229.48	790.49
5	Chan	-2.38	0.28	28.22	8.19	2.66	15.94	3.08	3.44	229.48	790.49
6	Chan	0.28	2.94	28.22	8.19	2.66	15.94	3.08	3.44	229.48	790.49
7	Chan	2.94	5.59	28.22	8.19	2.66	15.94	3.08	3.44	229.48	790.49
8	Chan	5.59	8.25	21.63	7.22	2.89	12.22	2.72	2.99	186	557
9	Chan	8.25	10.9	7.04	3.83	2.97	3.98	1.44	1.84	96.04	176.54
10	Chan	10.9	13.56	0.25	0.61	1.75	0.14	0.39	0.4	25.95	10.45

BRIDGE SECTION

CROSS SECTION OUTPUT — ***River Station*** 1727.5 BR U

Use the same data as in the contraction scour computation? No

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 BR U Profile: 100 Year

E.G. Elev (m)	113.14	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.46	Wt. n-Val.	0.06	0.04	0.04	
W.S. Elev (m)	112.68	Reach Len. (m)	19.7	19.7	19.7	
Crit W.S. (m)	111.95	Flow Area (m2)	0.6	58.73	0	
E.G. Slope (m/m)	0.004769	Area (m2)	1.89	58.73	0	60.62
Q Total (m3/s)	176.98	Flow (m3/s)	0.41	176.57	0	
Top Width (m)	31.01	Top Width (m)	6.64	24.24	0.14	
Vel Total (m/s)	2.98	Avg. Vel. (m/s)	0.68	3.01	0.17	
Max Chl Dpth (m)	3.07	Hydr. Depth (m)	0.46	2.42	0.03	1.95
Conv. Total (m3/s)	2562.7	Conv. (m3/s)	5.9	2556.8	0	
Length Wtd. (m)	19.7	Wetted Per. (m)	1.31	25.55	0.15	
Min Ch El (m)	109.61	Shear (N/m2)	21.27	107.48	1.42	
Alpha	1.01	Stream Power (N/m s)	784.24	0	0	
Frctn Loss (m)	0.09	Cum Volume (1000 m3)	9.8	53.93	4.21	
C & E Loss (m)	0.01	Cum SA (1000 m2)	23.39	23.07	6.42	

	Flow dis.	*manual*
Left WS Sta.	-18.51	-18.33
Left Flood Sta.	-13	-13
Left Main Channel	-11.69	
Right Main Channel	12.63	
Right Flood Sta.	12.55	12.69
Right WS Sta.		12.69
L' (left) 1.31	L (left)	6.64
L' (Right) 0.06	L (Right)	0.06

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		0.41	1.89		
Main	24.32	176.58	58.73	2.41	3.01
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 BR U Profile: 100 Year

Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1 LOB	-18.51	-17.13	0	0.12	1.21	0	0.1	0	4.7	0
2 LOB	-17.13	-15.75	0	0.27	1.38	0	0.19	0	9.1	0
3 LOB	-15.75	-14.38	0	0.39	1.38	0	0.28	0	13.19	0
4 LOB	-14.38	-13	0	0.51	1.38	0	0.37	0	17.28	0
5 LOB	-13	-11.69	0.41	0.6	1.31	0.23	0.46	0.68	21.27	14.48
6 Chan	-11.69	-9.27	4.19	2.67	2.71	2.37	1.1	1.57	46.13	72.3
7 Chan	-9.27	-6.84	14.39	5.6	2.71	8.13	2.31	2.57	96.75	248.45
8 Chan	-6.84	-4.42	24.46	7.41	2.46	13.82	3.06	3.3	140.96	465.19
9 Chan	-4.42	-1.99	24.83	7.44	2.42	14.03	3.07	3.34	143.47	479.04
10 Chan	-1.99	0.43	24.83	7.44	2.42	14.03	3.07	3.34	143.47	479.04
11 Chan	0.43	2.85	24.83	7.44	2.42	14.03	3.07	3.34	143.47	479.04
12 Chan	2.85	5.28	24.83	7.44	2.42	14.03	3.07	3.34	143.47	479.04
13 Chan	5.28	7.7	22.16	7.1	2.56	12.52	2.93	3.12	129.65	404.66
14 Chan	7.7	10.13	10.22	4.56	2.71	5.77	1.88	2.24	78.78	176.39
15 Chan	10.13	12.55	1.84	1.63	2.71	1.04	0.67	1.13	28.15	31.74
16 ROB	12.55	12.93	0	0	0.15	0	0.03	0.17	1.42	0.24

BRIDGE OUTPUT

River Station 1727.5

Low Chord Elev. 114.01
Mean Channelbed Elev. 109.61

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 Profile: 100 Year

E.G. US. (m)	113.2	Element	Inside BR US	Inside BR DS
W.S. US. (m)	112.72	E.G. Elev (m)	113.14	113.03
Q Total (m3/s)	176.98	W.S. Elev (m)	112.68	112.6
Q Bridge (m3/s)	176.98	Crit W.S. (m)	111.95	111.85
Q Weir (m3/s)		Max Chl Dpth (m)	3.07	3.02
Weir Sta Lft (m)		Vel Total (m/s)	2.98	2.91
Weir Sta Rgt (m)		Flow Area (m2)	59.33	60.8
Weir Submerg		Froude # Chl	0.62	0.61
Weir Max Depth (m)		Specif Force (m3)	135.04	134.78
Min El Weir Flow (m)	123.65	Hydr Depth (m)	2.31	2.26
Min El Prs (m)	120.54	W.P. Total (m)	27.02	28.28
Delta EG (m)	0.57	Conv. Total (m3/s)	2562.7	2597.4
Delta WS (m)	0.99	Top Width (m)	31.01	26.96
BR Open Area (m2)	269.06	Frctn Loss (m)	0.09	0.26
BR Open Vel (m/s)	2.98	C & E Loss (m)	0.01	0.14
Coef of Q		Shear Total (N/m2)	102.7	97.89
Br Sel Method	Energy only	Power Total (N/m s)	-1215.63	-1513.9

PROJECT NO. 151-273 **BRIDGE NO.** 06284 **UNIT:** Metric

Ref. HEC-18., May 2001 (4th ed.)

SUMMARY

Contraction Scour		Type:	**LIVE-BED**	Depth:	**0.00** m	Event:	**500-YR**
Local	**West Abut. #1**	**LEFT**	Eq.: Froehlich	Depth:	**0.51** m	Event:	**500-YR**
Abutment	**East Abut. #2**	**RIGHT**	Eq.: N/A	Depth:	**N/A** m	Event:	**500-YR**

CONTRACTION SCOUR

$V_c = K_u y^{1/6} D^{1/3}$ .....Eq. 5.1

= 0.52 *m/s* Critacal velocity above which bed material of size D and smaller will be transported

Ku = 6.19 m (6.19 in SI units; 11.17 in English units)

y = 2.89 m Average depth of flow upstream of the bridge

D = 0.00034 m Particle size for Vc *, m* (use D_{50})

V1 = 3.50 *m/s* The mean velocity of the flow in the main channel or overbank area upstream of the brige opening

Vc < V1 ***Thus, LIVE-BED CONTRACTION SCOUR***

Live-Bed Contraction Scour ==========

$Y_2/Y_1 = (Q_2/Q_1)^{6/7} (W_1/W_2)^{k_1}$ = 1.07 .....Eq. 5.2

$Y_s = Y_2 - Y_o$ m .....Eq. 5.3

= -0.06 m Average contraction scour depth

Y_1 = 2.89 m Average depth in the upstream main channel

Y_2 = 3.08 m Average depth in the contracted section

Y_o = 3.14 m Existing depth in the contracted section before scour

Q_1 = 269.00 m3/s Flow in the upstream channel transporting sediment

Q_2 = 266.57 m3/s Flow in the contracted channel

W_1 = 26.86 m Bottom width of the upstream main channel that is transporting bed material

W_2 = 24.24 m Bottom width of the main channel in the contracted section less pier width

k_1 = 0.69 Exponent determined below (V^*/ω = 9.67)

V^* = 0.4836 $=(T_o/\rho)^{1/2}$ or $(gY1\ S1)^{1/2}$, shear velocity in the upstream section , m/s

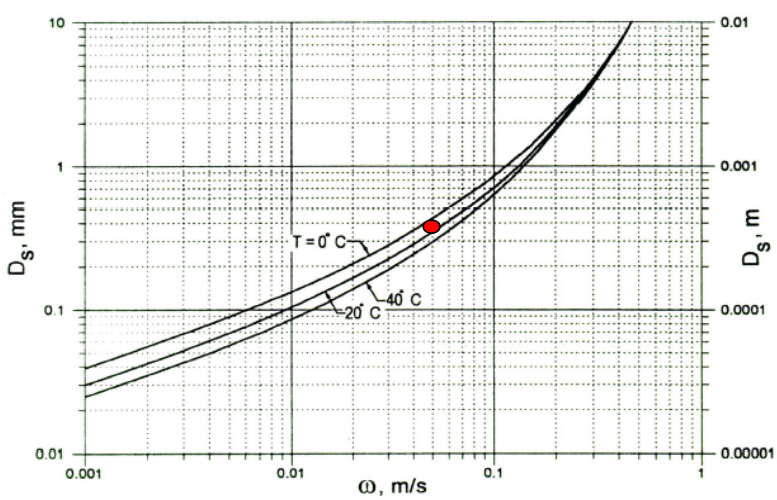
ω = 0.05 m/s Fall velocity of bed material based on the D_{50} (Figure 5.8)

g = 9.81 m/s^2 Acceleration of gravity

S1 = 0.00825 m/m Slope of energy gradeline of main channel

T_o = 133.94 Pa (N/m^2) Shear stess on the bed

ρ = 1000 kg/m^3 Density of water



V^*/ω	k1	*Mode of Bed Material Transport*
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

Figure 5.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Clear-Water Contraction Scour ==========

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2} \right]^{3/7}$$ .....Eq. 5.4

$y_s = y_2 - y_o$ **m** .....Eq. 5.5

=	**N/A**	**m**	Average contraction scour depth **LIVE-BED controls. Ignore this procedure**
y_2 =	14.88	m	Average equilibrium depth in the contracted section after contraction scour
y_o =	3.14	m	Average existing depth in the contracted section
Q =	269.01	m3/s	Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W
W =	24.24	m	Bottom width of the contracted section less pier widths
K_u =	0.0250		(0.025 in SI units; 0.0077 in English units)
D_m =	0.0004	m	Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in th contacted setion
D_{50} =	0.0003	m	Median diameter of bed material

Because D_{50} is not the largest particle in the bed material, the scoured section can be slightly armored. Therefore, the D_m is assumed to be 1.25 D_{50}. For stratified bed material the depth of scour can be determined by using the clear-water scour equation sequentially with successive D_m of the bed material layers.

Data Source

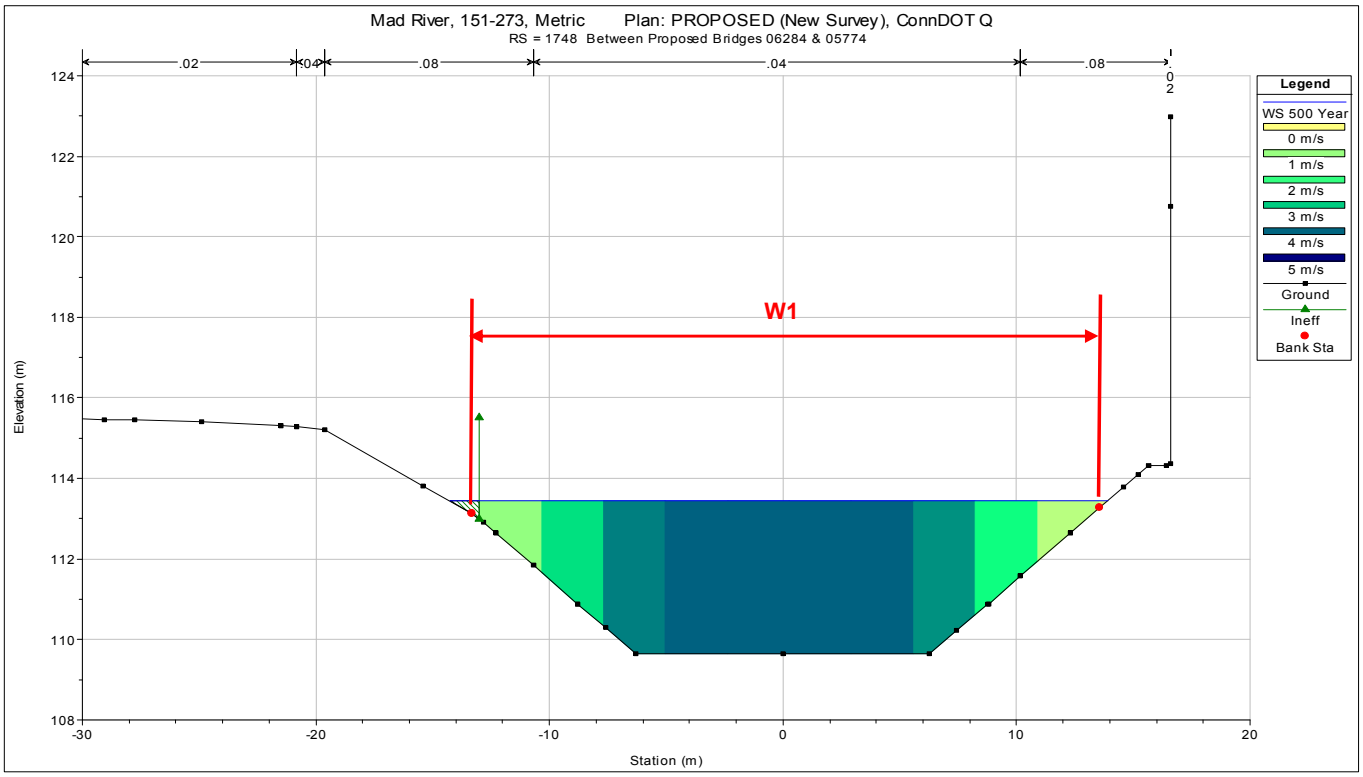
			From:	RS
Eq. 5.1				
y =	2.89	m	C	1748
V1 =	3.50	m	C	1727.5 BR U
Eq. 5.2 & 5.3				
Y1 =	2.89	m	C	1748
Yo =	3.14	m	C	1727.5 BR U
Q1 =	269	m3/s	C	1748
Q2 =	266.57	m3/s	C	1727.5 BR U
W1 =	26.86	m	C	1748
or	(n/a)	m (manual)		
W2 =	24.24	m	C	1727.5 BR U
or	(n/a)	m (manual)		
S1 =	0.00825	m/m	C	1748
To =	133.94	Pa (N/m^2)	C	1727.5 BR U
P2 =	0	m (pier width)		
Eq. 5.4 & 5.5				
Q =	269.01	m3/s	C	1727.5

Legends:

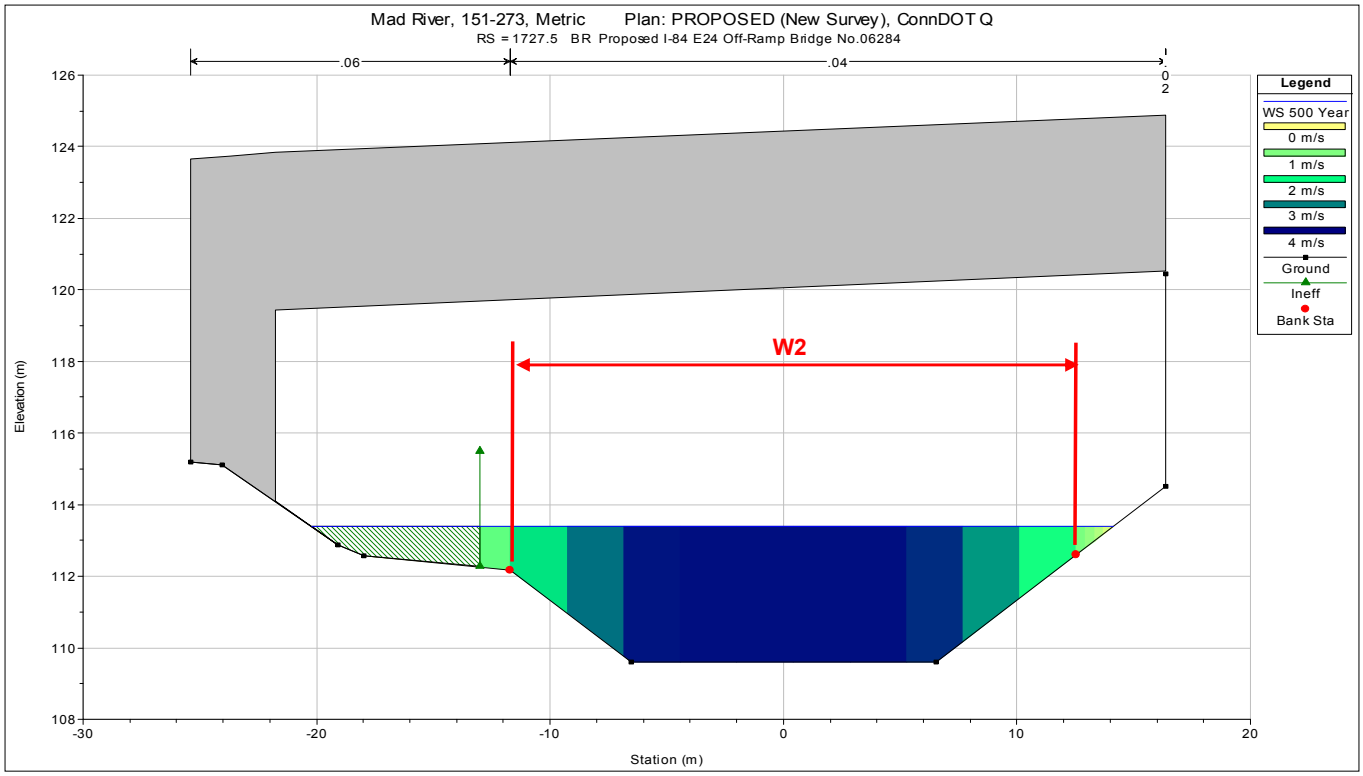
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections used for Constraction Scour Computations

UPSTREAM SECTION 1748



CONTRACTED SECTION 1727.5 BR U



UPSTREAM CHANNEL SECTION

River Station 1748 Event: 500-YR

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1748 Profile: 500 Year

E.G. Elev (m)	114.07	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.63	Wt. n-Val.		0.05	0.08	
W.S. Elev (m)	113.45	Reach Len. (m)	9.4	9.4	9.4	
Crit W.S. (m)	112.68	Flow Area (m2)		76.63	0.03	
E.G. Slope (m/m)	0.00825	Area (m2)	0.15	76.74	0.03	76.92
Q Total (m3/s)	269.01	Flow (m3/s)		269	0.01	
Top Width (m)	28.19	Top Width (m)	0.98	26.86	0.35	
Vel Total (m/s)	3.51	Avg. Vel. (m/s)		3.51	0.21	
Max Chl Dpth (m)	3.81	Hydr. Depth (m)		2.89	0.09	2.73
Conv. Total (m3/s)	2961.8	Conv. (m3/s)		2961.7	0.1	
Length Wtd. (m)	9.4	Wetted Per. (m)		28.21	0.39	
Min Ch El (m)	109.64	Shear (N/m2)		219.74	6.37	
Alpha	1	Stream Power (N/m s)	795.26	0	0	
Frctn Loss (m)	0.06	Cum Volume (1000 m3)	34.17	69.76	12.22	
C & E Loss (m)	0	Cum SA (1000 m2)	48.36	23.81	14.43	

	Flow dis.	*manual*
Left WS Sta.	-15.29	-14.28
Left Convy Sta.		-14.28
Left Main Channel	-14.28	
Right Main Channel	13.91	
Right Convy Sta.		13.91
Right WS Sta.		13.91
L' (left) 0	L (left)	0
L' (Right) 0	L (Right)	0

HEC-RAS FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT					
Main	28.19	269.02	76.93	2.73	3.50
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1748 Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)
1	LOB	-15.29	-13.3	0	0.15	1.03	0	0.15	0	11.82
2	Chan	-13.3	-13	0	0.11	0.33	0	0.38	0	27.58
3	Chan	-13	10.34	3.15	2.97	2.97	1.17	1.12	1.06	80.75
4	Chan	-10.34	-7.69	18.16	6.49	2.97	6.75	2.44	2.8	176.93
5	Chan	-7.69	-5.03	36.15	9.62	2.82	13.44	3.62	3.76	275.57
6	Chan	-5.03	-2.38	40.92	10.11	2.66	15.21	3.81	4.05	307.92
7	Chan	-2.38	0.28	40.92	10.11	2.66	15.21	3.81	4.05	307.92
8	Chan	0.28	2.94	40.92	10.11	2.66	15.21	3.81	4.05	307.92
9	Chan	2.94	5.59	40.92	10.11	2.66	15.21	3.81	4.05	307.92
10	Chan	5.59	8.25	32.7	9.14	2.89	12.16	3.44	3.58	255.94
11	Chan	8.25	10.9	13.64	5.75	2.97	5.07	2.16	2.37	156.68
12	Chan	10.9	13.56	1.53	2.23	2.97	0.57	0.84	0.69	60.75
13	ROB	13.56	13.86	0.01	0.03	0.34	0	0.1	0.21	7.22
14	ROB	13.86	14.17	0	0	0.05	0	0.01	0.05	0.85
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CONTRACTED CHANNEL SECTION

River Station 1727.5 BR U

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 BR U Profile: 500 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	114.01	Element				
Vel Head (m)	0.62	Wt. n-Val.	0.06	0.04	0.04	
W.S. Elev (m)	113.39	Reach Len. (m)	19.7	19.7	19.7	
Crit W.S. (m)	112.59	Flow Area (m2)	1.53	76.07	0.62	
E.G. Slope (m/m)	0.004588	Area (m2)	7.39	76.07	0.62	84.08
Q Total (m3/s)	269.01	Flow (m3/s)	1.92	266.57	0.52	
Top Width (m)	34.34	Top Width (m)	8.53	24.24	1.57	
Vel Total (m/s)	3.44	Avg. Vel. (m/s)	1.25	3.5	0.84	
Max Chl Dpth (m)	3.78	Hydr. Depth (m)	1.17	3.14	0.39	2.45
Conv. Total (m3/s)	3971.6	Conv. (m3/s)	28.4	3935.5	7.6	
Length Wtd. (m)	19.7	Wetted Per. (m)	1.31	25.55	1.76	
Min Ch El (m)	109.61	Shear (N/m2)	52.59	133.94	15.77	
Alpha	1.03	Stream Power (N/m s)	784.24	0	0	
Frctn Loss (m)	0.09	Cum Volume (1000 m3)	34.13	69.04	12.22	
C & E Loss (m)	0.02	Cum SA (1000 m2)	48.32	23.57	14.42	

	Flow dis.	*manual*
Left WS Sta.	-21.26	-20.22
Left Flood Sta.	-13	
Left Main Channel	-11.69	
Right Main Channel	14.11	
Right Flood Sta.	14.08	14.12
Right WS Sta.		14.12
L' (left) 1.31	L (left)	8.53
L' (Right) 0.01	L (Right)	0.01

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		1.92	7.37		
Main	25.8	267.09	76.69	2.97	3.48
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 BR U Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)
1	LOB	-21.26	-19.88	0	0.03	0.37	0	0.08	0	3.11
2	LOB	-19.88	-18.51	0	0.6	1.47	0	0.44	0	18.39
3	LOB	-18.51	-17.13	0	1.1	1.4	0	0.8	0	35.49
4	LOB	-17.13	-15.75	0	1.25	1.38	0	0.91	0	40.88
5	LOB	-15.75	-14.38	0	1.37	1.38	0	1	0	44.82
6	LOB	-14.38	-13	0	1.49	1.38	0	1.09	0	48.75
7	LOB	-13	-11.69	1.92	1.53	1.31	0.71	1.17	1.25	52.59
8	Chan	-11.69	-9.27	9.76	4.41	2.71	3.63	1.82	2.21	73.18
9	Chan	-9.27	-6.84	22.84	7.34	2.71	8.49	3.03	3.11	121.88
10	Chan	-6.84	-4.42	35.16	9.15	2.46	13.07	3.77	3.84	167.33
11	Chan	-4.42	-1.99	35.65	9.17	2.42	13.25	3.78	3.89	170.21
12	Chan	-1.99	0.43	35.65	9.17	2.42	13.25	3.78	3.89	170.21
13	Chan	0.43	2.85	35.65	9.17	2.42	13.25	3.78	3.89	170.21
14	Chan	2.85	5.28	35.65	9.17	2.42	13.25	3.78	3.89	170.21
15	Chan	5.28	7.7	32.29	8.83	2.56	12	3.64	3.66	155.2
16	Chan	7.7	10.13	17.7	6.3	2.71	6.58	2.6	2.81	104.59
17	Chan	10.13	12.55	6.23	3.37	2.71	2.31	1.39	1.85	55.88
18	ROB	12.55	12.93	0.27	0.26	0.43	0.1	0.69	1.04	27.69
19	ROB	12.93	13.32	0.16	0.19	0.43	0.06	0.5	0.84	20
20	ROB	13.32	13.7	0.07	0.12	0.43	0.03	0.31	0.61	12.31
21	ROB	13.7	14.08	0.01	0.04	0.43	0.01	0.11	0.32	4.62
22	ROB	14.08	14.47	0	0	0.04	0	0.01	0.06	0.39
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LIVE SCOUR AT ABUTMENTS

Froehlich's Live-Bed Abutment Scour Equation — LEFT — RIGHT ==========

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 1 =$ **1.54** **N/A** .....Eq. 7.1

Amended Local Scour Equation

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 0.05 =$ **0.59** **N/A** .....CT DOT DM Pg 9B-2

	LEFT	RIGHT		
Ys =	**0.51**	**N/A**	**m**	Scour depth <== using Amended equation
K_1 =	0.82	0.55		Coeffcient for abutment shape (see Table 7.1 and Figrue 7.6)
K_2 =	1.05	0.91		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
θ =	135	45		
				θ < 90 degrees if embankment points downstream
				θ > 90 degrees if embankment points upstream
				(see Figure 7.5 for definition of θ)
L' =	1.31	0.00	m	Length of active flow obstructed by the embankment (see Figure 7.4)
Ae =	7.37	0.00	m^2	Flow area of the approach cross section obstructed by the embankment
Fr =	0.09	N/A		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment
Ve =	0.26	N/A	m/s	Qe/Ae
Qe =	1.92	0	m^3/s	Flow obstructed by the abutment and approach embankment
Ya =	0.86	N/A	m	Ae/L, Average depth of flow on the floodplain
L =	8.53	0	m	Length of embankment projected normal to the flow

Table 7.1. Abutment Shape Coefficients.

Description	K_1
Vertical-wall abutment	1.00
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

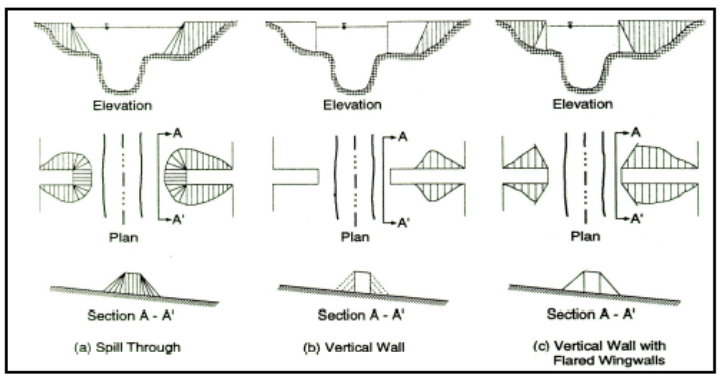


Figure 7.6. Abutment shape.

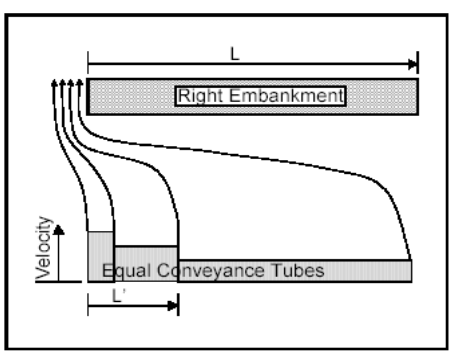


Figure 7.4. Determination of length of embankment blocking live flow for abutment scour estimation.

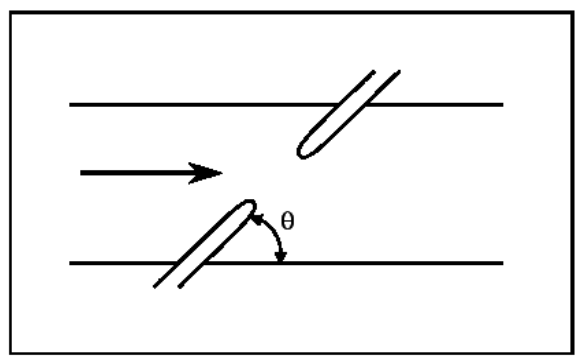


Figure 7.5. Orientation of embankment angle, θ, to the flow.

HIRE Live-Bed Abutment Scour Equation ==========

		LEFT	RIGHT	
Applicability check:	L/Y_1 =	3	N/A	*Use HIRE Eq. only if $L/Y_1 > 25$*
$Y_s/Y_1 = 4\ Fr^{0.33}\ K_1/0.55\ K_2$ =		**N/A**	**N/A**	.....Eq. 7.1

	LEFT	RIGHT		
Ys =	**N/A**	**N/A**	**m**	Scour depth (N/A if $L/Y_1 < 25$)
K1 =	0.82	0.55		Coeffcient for abutment shape (see Table 7.1 on RIGHT)
K2 =	1.05	0.91		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
Y1 =	2.89	N/A	m	Depth of flow at the abutment on the overbank or in the main channel,
Fr =	0.09	N/A		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment

Data Source

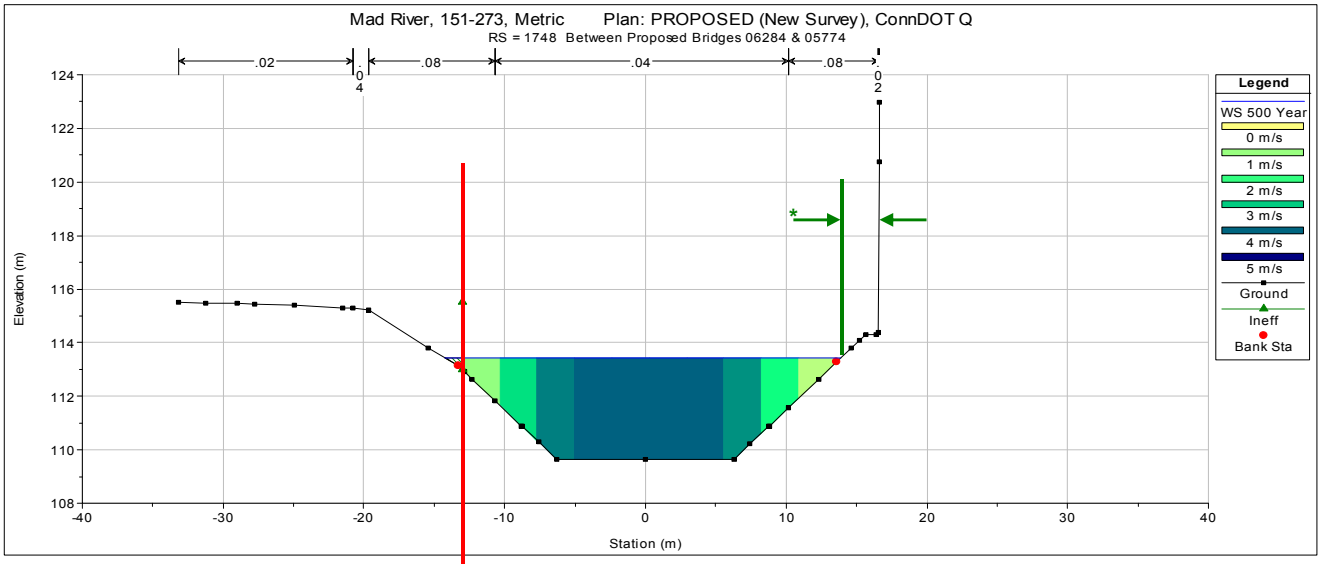
Eq. 7.1				From:	RS
LT				UF	
	L' =	1.31	m	D	1727.5 BR U
	Ae =	7.37	m2	D	1727.5 BR U
	Qe =	1.92	m3/s	D	1727.5 BR U
	L =	8.53	m	D	1727.5 BR U
RT				UC	
	L' =	0	m	D	1748
	Ae =	0	m2	D	1748
	Qe =	0	m3/s	D	1748
	L =	0	m	D	1748

Legends:

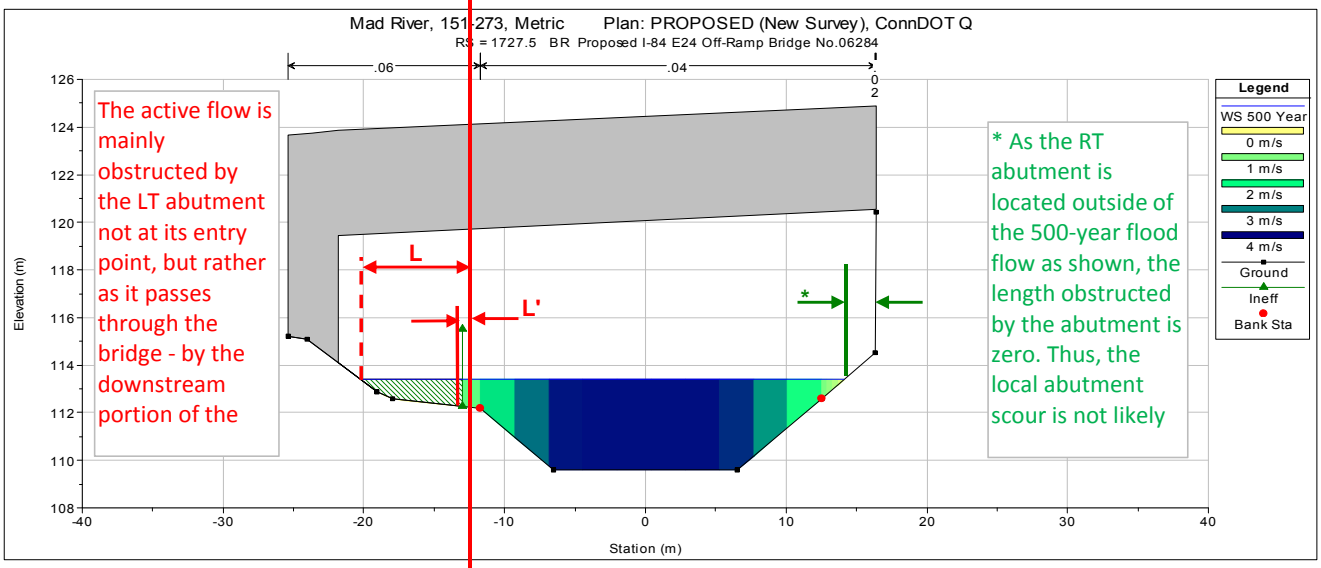
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections Used for Local Abutment Scour Computations

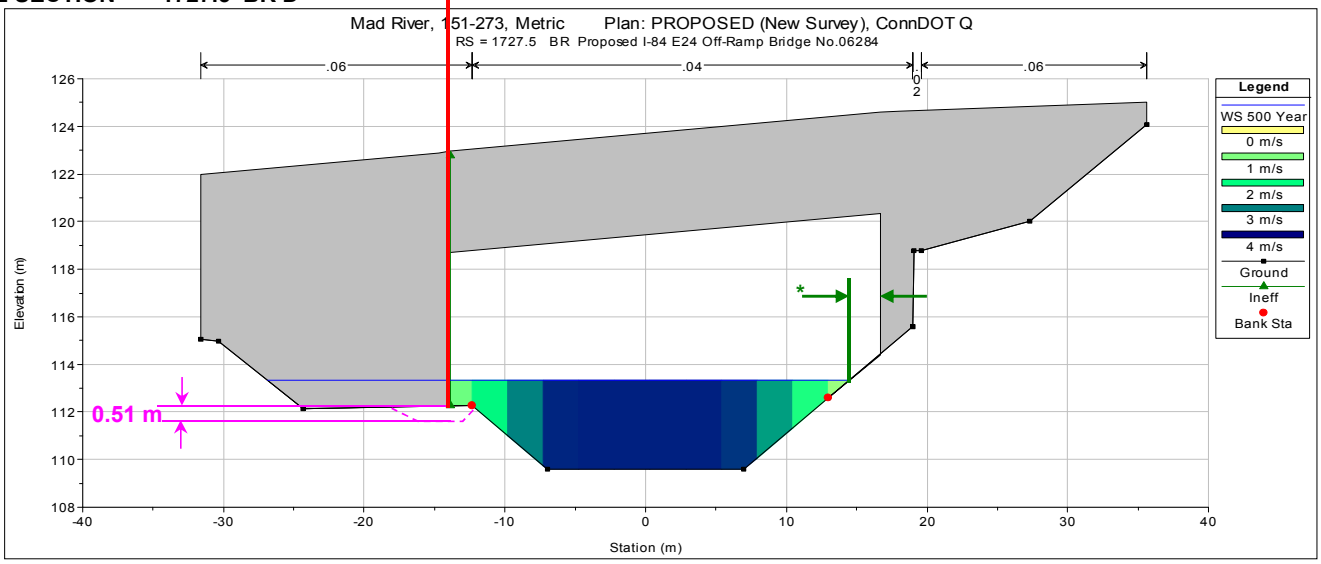
APPROACH SECTION 1748



BRIDGE SECTION 1727.5 BR U



BRIDGE SECTION 1727.5 BR D



UPSTREAM APPROACH CHANNEL SECTION

River Station 1748 Event: 500-YR

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computation?*** Yes

Plan: PR_DOT Mad River Reach 1 RS: 1748 Profile: 500 Year

E.G. Elev (m)	114.07	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.63	Wt. n-Val.		0.05	0.08	
W.S. Elev (m)	113.45	Reach Len. (m)	9.4	9.4	9.4	
Crit W.S. (m)	112.68	Flow Area (m2)		76.63	0.03	
E.G. Slope (m/m)	0.00825	Area (m2)	0.15	76.74	0.03	76.92
Q Total (m3/s)	269.01	Flow (m3/s)		269	0.01	
Top Width (m)	28.19	Top Width (m)	0.98	26.86	0.35	
Vel Total (m/s)	3.51	Avg. Vel. (m/s)		3.51	0.21	
Max Chl Dpth (m)	3.81	Hydr. Depth (m)		2.89	0.09	2.73
Conv. Total (m3/s)	2961.8	Conv. (m3/s)		2961.7	0.1	
Length Wtd. (m)	9.4	Wetted Per. (m)		28.21	0.39	
Min Ch El (m)	109.64	Shear (N/m2)		219.74	6.37	
Alpha	1	Stream Power (N/m s)	795.26	0	0	
Frctn Loss (m)	0.06	Cum Volume (1000 m3)	34.17	69.76	12.22	
C & E Loss (m)	0	Cum SA (1000 m2)	48.36	23.81	14.43	

	Flow dis. (data)	*manual*
Left WS Sta.		-14.28
Left Flood Sta.	-13	-14.28
Left Main Channel	-10.34	
Right Main Channel	13.91	
Right Flood Sta.	13.56	13.91
Right WS Sta.	14.17	13.91
L' (left) 3.94	L (left)	3.94
L' (Right) 0	L (Right)	0

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		3.15	3.23		
Main	24.25	265.87	73.7	3.04	3.61
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1748 Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)
1	LOB	-15.29	-13.3	0	0.15	1.03	0	0.15	0	11.82
2	Chan	-13.3	-13	0	0.11	0.33	0	0.38	0	27.58
3	Chan	-13	-10.34	3.15	2.97	2.97	1.17	1.12	1.06	80.75
4	Chan	-10.34	-7.69	18.16	6.49	2.97	6.75	2.44	2.8	176.93
5	Chan	-7.69	-5.03	36.15	9.62	2.82	13.44	3.62	3.76	275.57
6	Chan	-5.03	-2.38	40.92	10.11	2.66	15.21	3.81	4.05	307.92
7	Chan	-2.38	0.28	40.92	10.11	2.66	15.21	3.81	4.05	307.92
8	Chan	0.28	2.94	40.92	10.11	2.66	15.21	3.81	4.05	307.92
9	Chan	2.94	5.59	40.92	10.11	2.66	15.21	3.81	4.05	307.92
10	Chan	5.59	8.25	32.7	9.14	2.89	12.16	3.44	3.58	255.94
11	Chan	8.25	10.9	13.64	5.75	2.97	5.07	2.16	2.37	156.68
12	Chan	10.9	13.56	1.53	2.23	2.97	0.57	0.84	0.69	60.75
13	ROB	13.56	13.86	0.01	0.03	0.34	0	0.1	0.21	7.22
14	ROB	13.86	14.17	0	0	0.05	0	0.01	0.05	0.85
15										
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BRIDGE SECTION

River Station 1727.5 BR U

CROSS SECTION OUTPUT *Use the same data as in the contraction scour computation?* No

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 BR U Profile: 500 Year

E.G. Elev (m)	114.01	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.62	Wt. n-Val.	0.06	0.04	0.04	
W.S. Elev (m)	113.39	Reach Len. (m)	19.7	19.7	19.7	
Crit W.S. (m)	112.59	Flow Area (m2)	1.53	76.07	0.62	
E.G. Slope (m/m)	0.004588	Area (m2)	7.39	76.07	0.62	84.08
Q Total (m3/s)	269.01	Flow (m3/s)	1.92	266.57	0.52	
Top Width (m)	34.34	Top Width (m)	8.53	24.24	1.57	
Vel Total (m/s)	3.44	Avg. Vel. (m/s)	1.25	3.5	0.84	
Max Chl Dpth (m)	3.78	Hydr. Depth (m)	1.17	3.14	0.39	2.45
Conv. Total (m3/s)	3971.6	Conv. (m3/s)	28.4	3935.5	7.6	
Length Wtd. (m)	19.7	Wetted Per. (m)	1.31	25.55	1.76	
Min Ch El (m)	109.61	Shear (N/m2)	52.59	133.94	15.77	
Alpha	1.03	Stream Power (N/m s)	784.24	0	0	
Frctn Loss (m)	0.09	Cum Volume (1000 m3)	34.13	69.04	12.22	
C & E Loss (m)	0.02	Cum SA (1000 m2)	48.32	23.57	14.42	

	Flow dis.	*manual*
Left WS Sta.	-21.26	-20.22
Left Flood Sta.	(data)	-13
Left Main Channel	-11.69	(data)
Right Main Channel	14.12	(data)
Right Flood Sta.	(data)	14.12
Right WS Sta.	14.47	14.12
L' (left) 1.31	L (left)	8.53
L' (Right) 0	L (Right)	0

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		1.92	7.37		
Main	25.81	267.09	76.69	2.97	3.48
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1727.5 BR U Profile: 500 Year

Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1 LOB	-21.26	-19.88	0	0.03	0.37	0	0.08	0	3.11	0
2 LOB	-19.88	-18.51	0	0.6	1.47	0	0.44	0	18.39	0
3 LOB	-18.51	-17.13	0	1.1	1.4	0	0.8	0	35.49	0
4 LOB	-17.13	-15.75	0	1.25	1.38	0	0.91	0	40.88	0
5 LOB	-15.75	-14.38	0	1.37	1.38	0	1	0	44.82	0
6 LOB	-14.38	-13	0	1.49	1.38	0	1.09	0	48.75	0
7 LOB	-13	-11.69	1.92	1.53	1.31	0.71	1.17	1.25	52.59	65.88
8 Chan	-11.69	-9.27	9.76	4.41	2.71	3.63	1.82	2.21	73.18	162.07
9 Chan	-9.27	-6.84	22.84	7.34	2.71	8.49	3.03	3.11	121.88	379.25
10 Chan	-6.84	-4.42	35.16	9.15	2.46	13.07	3.77	3.84	167.33	643.18
11 Chan	-4.42	-1.99	35.65	9.17	2.42	13.25	3.78	3.89	170.21	661.69
12 Chan	-1.99	0.43	35.65	9.17	2.42	13.25	3.78	3.89	170.21	661.69
13 Chan	0.43	2.85	35.65	9.17	2.42	13.25	3.78	3.89	170.21	661.69
14 Chan	2.85	5.28	35.65	9.17	2.42	13.25	3.78	3.89	170.21	661.69
15 Chan	5.28	7.7	32.29	8.83	2.56	12	3.64	3.66	155.2	567.34
16 Chan	7.7	10.13	17.7	6.3	2.71	6.58	2.6	2.81	104.59	293.88
17 Chan	10.13	12.55	6.23	3.37	2.71	2.31	1.39	1.85	55.88	103.39
18 ROB	12.55	12.93	0.27	0.26	0.43	0.1	0.69	1.04	27.69	28.78
19 ROB	12.93	13.32	0.16	0.19	0.43	0.06	0.5	0.84	20	16.73
20 ROB	13.32	13.7	0.07	0.12	0.43	0.03	0.31	0.61	12.31	7.45
21 ROB	13.7	14.08	0.01	0.04	0.43	0.01	0.11	0.32	4.62	1.46
22 ROB	14.08	14.47	0	0	0.04	0	0.01	0.06	0.39	0.02

BRIDGE OUTPUT

River Station 1727.5

Low Chord Elev. 114.01
Mean Channelbed Elev. 109.61

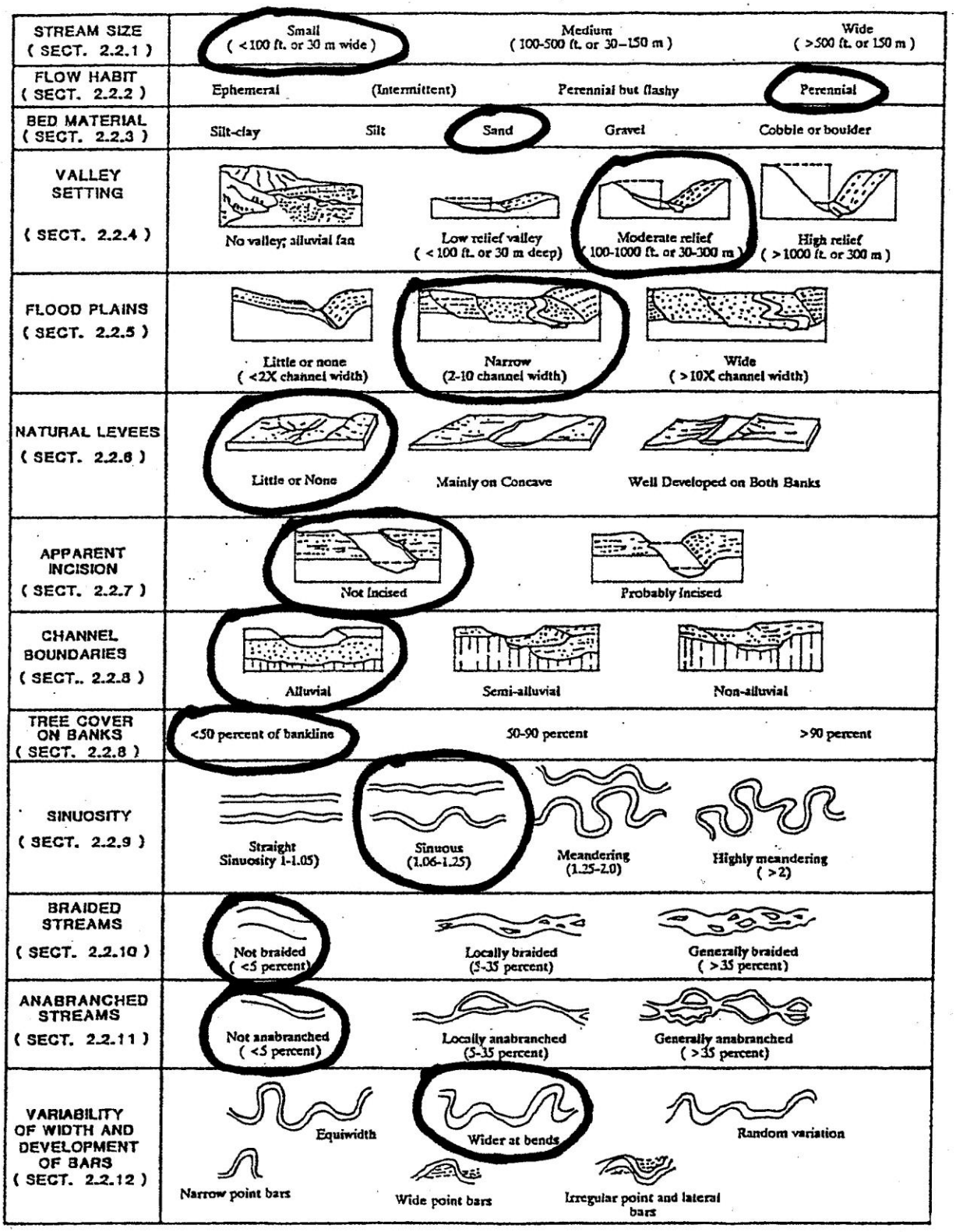
Plan: PR_DOT Mad River Reach 1 RS: 1727.5 Profile: 500 Year

E.G. US. (m)	114.07	Element	Inside BR US	Inside BR DS
W.S. US. (m)	113.45	E.G. Elev (m)	114.01	113.91
Q Total (m3/s)	269.01	W.S. Elev (m)	113.39	113.33
Q Bridge (m3/s)	269.01	Crit W.S. (m)	112.59	112.48
Q Weir (m3/s)		Max Chl Dpth (m)	3.78	3.75
Weir Sta Lft (m)		Vel Total (m/s)	3.44	3.32
Weir Sta Rgt (m)		Flow Area (m2)	78.22	80.98
Weir Submerg		Froude # Chl	0.63	0.61
Weir Max Depth (m)		Specif Force (m3)	225.53	225.89
Min El Weir Flow (m)	123.65	Hydr Depth (m)	2.88	2.85
Min El Prs (m)	120.54	W.P. Total (m)	28.62	29.91
Delta EG (m)	0.58	Conv. Total (m3/s)	3971.6	4086.9
Delta WS (m)	1.11	Top Width (m)	34.34	28.42
BR Open Area (m2)	269.06	Frctn Loss (m)	0.09	0.24
BR Open Vel (m/s)	3.44	C & E Loss (m)	0.02	0.17
Coef of Q		Shear Total (N/m2)	122.96	115.04
Br Sel Method	Energy only	Power Total (N/m s)	-1215.63	-1513.9

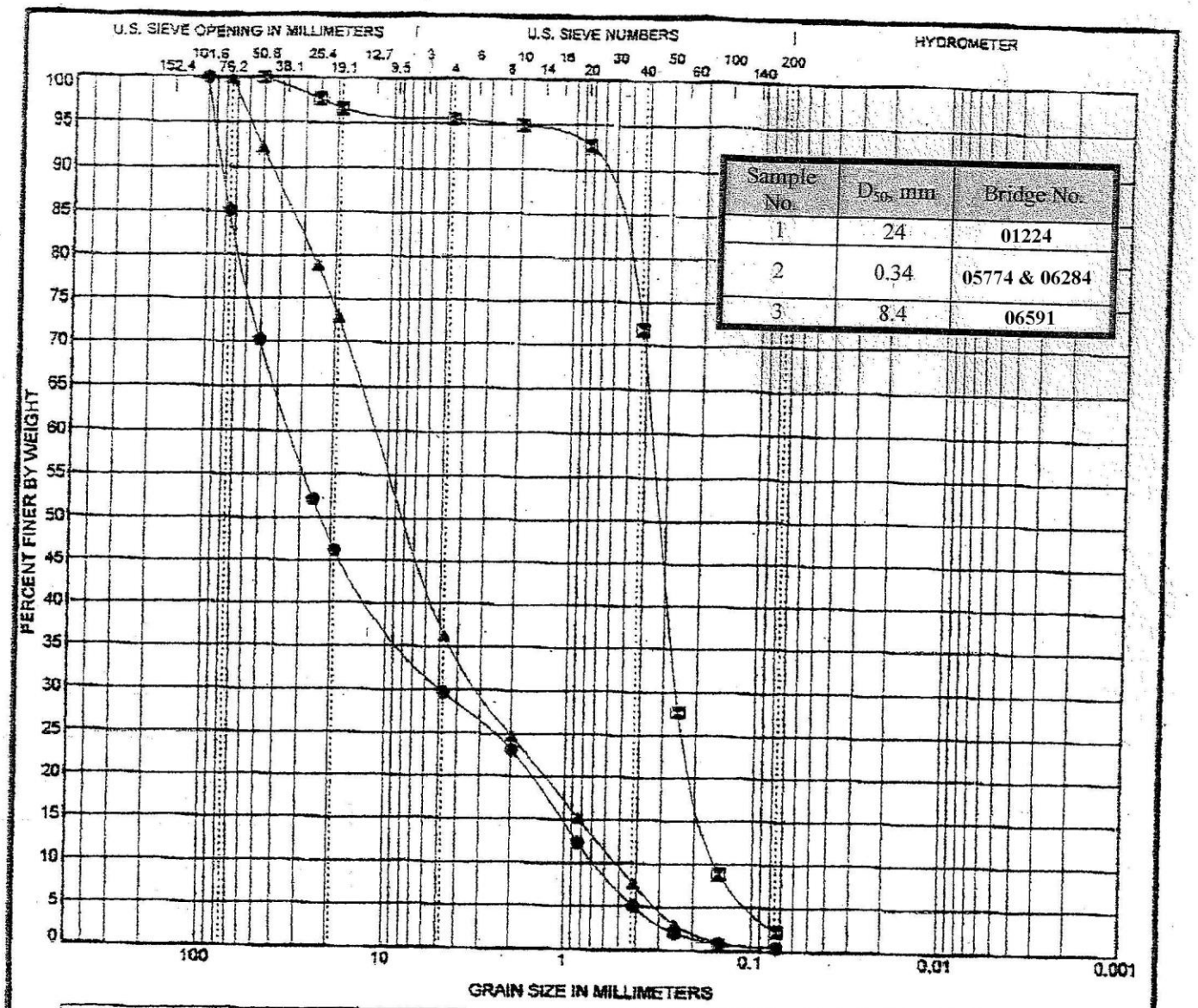
Appendix C:

Geomorphic Characterization
and
Grain Size Distribution

Mad River, Waterbury, CT
Proposed Bridge No. 06284



Geomorphic factors that affect stream stability



Sample No.	D_{50}, mm	Bridge No.
1	24	01224
2	0.34	05774 & 06284
3	8.4	06591

	COBBLES	% GRAVEL			% SAND		% FINES	
		COARSE	MEDIUM	FINE	COARSE	FINE	% SILT	% CLAY
●	14.9	32.4	14.3	14.8	18.0	4.7	0.4	
■	0.0	2.4	1.5	1.1	23.2	69.6	2.2	
▲	0.0	20.8	24.5	29.8	17.0	7.2	0.5	

	Expl. No.	Sample No.	Depth (m)	LL	PL	PI	Water Content (%)	Cc	Cu
●	TP	1					6.2	1.04	51.02
■	TP	2					21.2	1.17	2.38
▲	TP	3					5.6	1.46	22.48

Sample Description

● Brown coarse to fine GRAVEL, little cobbles, little coarse sand, trace fine sand

■ Light brown coarse to fine SAND, trace coarse to fine gravel, trace silt

▲ Orange brown coarse to fine GRAVEL, little coarse sand, trace fine sand

Remarks:

HALEY & ALDRICH
Glastonbury, Connecticut

I-84 Reconstruction
Waterbury, Connecticut
State Project No.:

GRAIN SIZE DISTRIBUTION

Date: 12/17/2000

File No.: 91313-100

CONN DOT SIEVE 91313S.GPJ US LAB.GDT 12/20/00